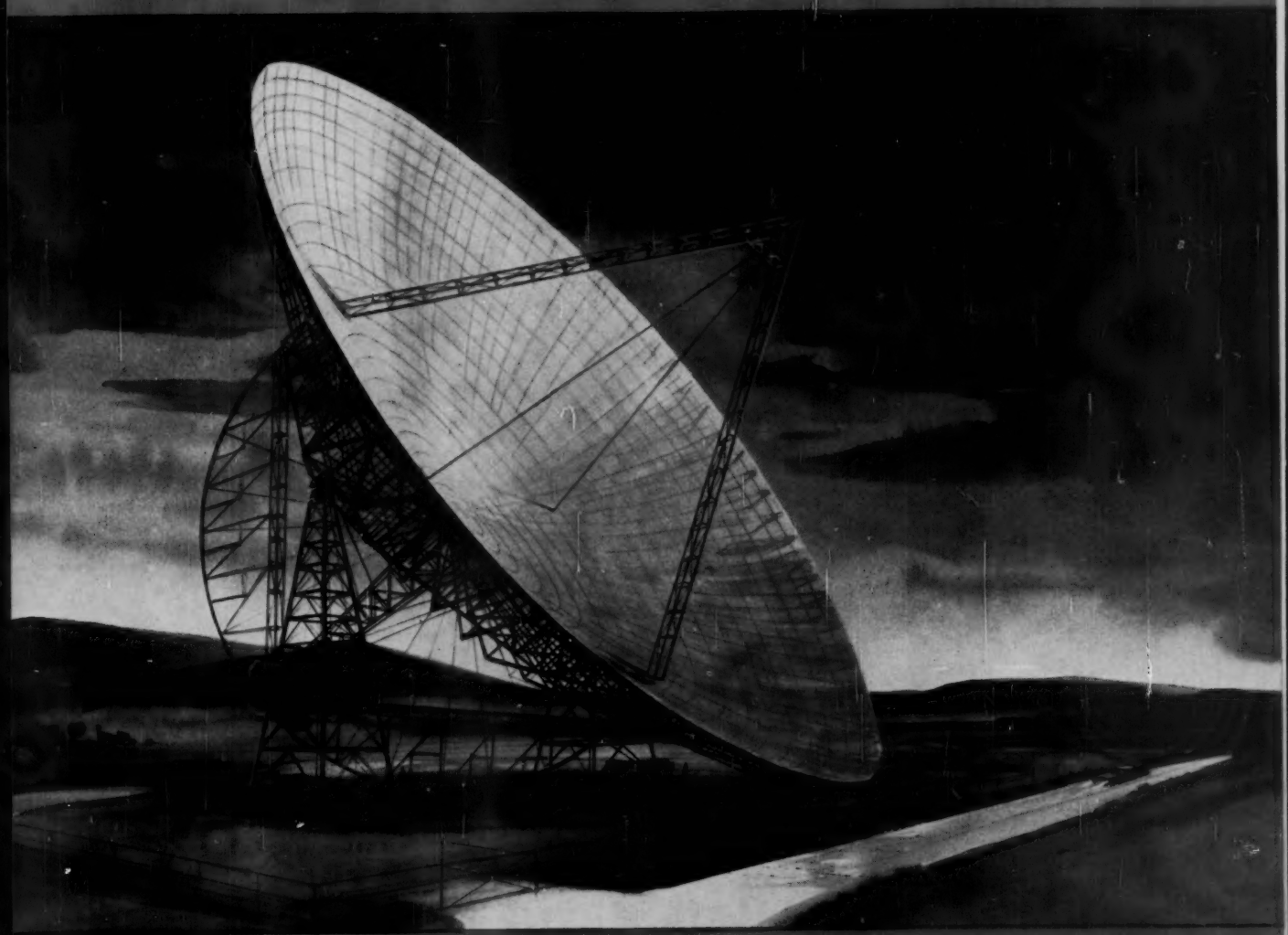
Sky and TELESCOPE



Green Bank 300-foot radio telescope

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Vol. XXI, No. 6

JUNE, 1961

50 cents

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Some Astronomical Aspects of Life in the Universe

Why Is Starlight Polarized?

Solar Disturbances and Radio Communication Forecasts

The Elusive Maximum of S Andromedae

Soviet Solar Eclipse Observations

Northern and Southern Star Charts

Who saw the Crab Nebula first?

The year was 1054 and Chinese and Japanese astronomers dutifully recorded a heavenly explosion that occurred some 4,000 years before they saw it. This nova, then bright as Jupiter, faded from sight until the 18th century, when telescope-equipped observers rediscovered the nova remains, later named the Crab Nebula.

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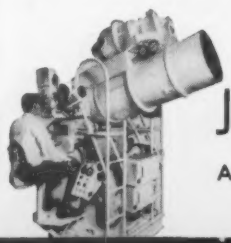

J. W. FECKER DIVISION

AMERICAN OPTICAL COMPANY

Sky and TELESCOPE

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Vol. XXI, No. 6 JUNE, 1961

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A New Radio Telescope at Green Bank

SOMETIME next year astronomers at the National Radio Astronomy Observatory will begin to observe the sky with a 300-foot radio telescope. Although limited to pointing along the plane of the meridian, this instrument will add greatly to present facilities at Green Bank, West Virginia, where the construction of a 140-foot completely steerable reflector is under way (SKY AND TELESCOPE, January, 1960, page 143). For a time, the 300-foot will be the largest movable paraboloid in the world; later it will be exceeded by the U. S. Navy's 600-foot antenna at Sugar Grove, West Virginia.

Supported by two towers 87 feet high, the giant dish will turn on an east-west horizontal axis as it sweeps the meridian to within 30 degrees of the north and south horizon points, where its own immense size limits it, as the front-cover picture shows. But all declinations from the north celestial pole to 22 degrees south of the celestial equator will be observable with this transit-type antenna.

Observations are to be made by setting the reflector to the proper declination and measuring a cosmic radio source as the antenna beam is swept over it by the earth's rotation. Thus the whole accessible sky can be surveyed, one declination zone at a time.

Designed for wave lengths as short as the 21-centimeter neutral hydrogen line, the reflecting surface will be made of aluminum wire mesh with $\frac{3}{4}$-inch spaces between strands. Although 78,000 square feet in area, its surface figure is to remain within one inch of a true paraboloid at all pointing angles. The focus, $128\frac{1}{2}$ feet above the dish, has a support for as much as 500 pounds of receiving equipment, held within two inches of the proper position with respect to the reflector. The feed will tower 225 feet above ground when the telescope points overhead.

The electronic components, to be built at least in part by NRAO staff members, include a multichannel receiver for measuring the neutral hydrogen radiation from both the Milky Way and external galaxies. The radio spectra of galaxies will be recorded, while the tremendous signal-collecting area of the antenna will permit deep-sky surveys for distant, faint radio sources.

In spite of the 460-ton bulk of the moving parts, the dish will be tiltable by winch and cable at a rate of 10 degrees per minute along the meridian, and it may be set in declination with an accuracy of two minutes of arc. Designed by R. D. Hall and E. R. Faelten, the structure will be sufficiently rigid to allow precise observations in winds up to 15

(Continued on page 327)

Some Astronomical Aspects of Life in the Universe

SU-SHU HUANG, *Institute for Advanced Study, Princeton, New Jersey*

THREE different ways by which matter interacts are gravitational, nuclear, and chemical. As our knowledge now stands, it appears that the behavior of all matter in the universe — from shining stars to exuberant life on the earth — may eventually be explained in terms of these interactions. Indeed, the emergence of life in general, and on earth in particular, is a net result of all three.

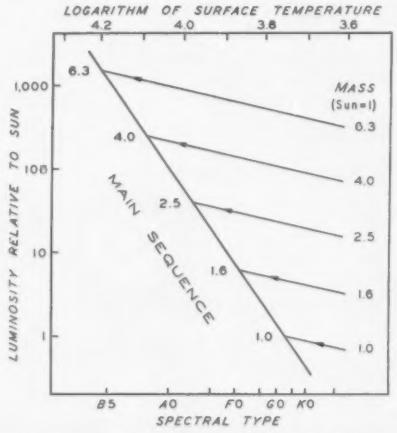
All forms of life must rely for maintenance on a stellar source of energy. Therefore, the nature and evolution of a star control the emergence and development of life. There is no doubt now that stars condense from gas and dust in the interstellar clouds, a newly formed star's temperature being very low because the interstellar gas is quite cool. As the star contracts, its temperature increases, and it moves from the lower right-hand corner of the Hertzsprung-Russell diagram toward the left side. The accompanying chart shows the early evolutionary tracks of stars of different masses, which can be roughly represented by straight lines.*

Gravitational contraction stops when the internal temperature becomes high enough for thermonuclear reactions to begin to convert hydrogen into helium. These reactions supply energy equal to that radiated by the star, which therefore maintains an equilibrium condition with constant luminosity for a long time. Such a state of affairs corresponds to a star on the main sequence.

The time of contraction to the main sequence depends on the mass, as the table shows. The time-scales given here are longer than usually cited because we have taken into account the change in luminosity of the star during its contraction.

A star of a certain mass will arrive at the main sequence with a definite spectral type and luminosity, and its character changes only slightly during the long period in which the hydrogen in its core is being consumed. Once the central hydrogen is exhausted, the star evolves quite rapidly toward the right, to become a giant or supergiant — very different in size and surface brightness from before.

It is obvious from the table that time-scales on the main sequence are much longer than those of contraction. This explains why about 90 per cent of observed stars are to be found on the main sequence. The stay of a more massive star on the main sequence is shorter than that of a less massive star, as it dissipates its energy much faster. Thus, an *O* star remains in this state for only a few million years, compared to an *M* star's 100 billion.



A contracting newborn star evolves leftward in this diagram to the main sequence, where a long stay should favor development of life on any planets the star may have.

From this brief look at stellar life histories, it is clear that gravitation holds a star together while nuclear interactions release the energy it radiates. The third kind of reaction, chemical, does not play a significant role in shaping a star, yet chemical action is responsible for the emergence and evolution of living organisms. And although we can predict that in about 10 billion years or less our sun will become a white dwarf, there is no way of telling how man will evolve in even 10 million years.

What is the reason for this? Gravitational interaction is very simple and is described by Newton's law of gravitation. The number of possible nuclear interactions is very large indeed, since there are hundreds of different atomic nuclei; nevertheless, we could still list all conceivable reactions. Hence we can compute them and even predict the evolution of stars by the law of gravitation and our knowledge of nuclear physics.

But how big is the total number of chemical reactions — both inorganic and organic — that one may conceive? Unable to estimate such a number, I am probably safe in saying that it is larger than any astronomical figure we can find in our textbooks. It is this wealth of chemical activity that makes a prediction of the emergence and evolution of living organisms difficult, if not permanently elusive.

If we cannot compute the time-scale of biological evolution, we must find it out empirically. Here on earth it took about three billion years for humans to evolve from atoms (see page 314). I have suggested earlier that since biological evolution occurs through the random processes of mutation and selection, its average time-scale is probably of the same order of magnitude — a few billion years. On this basis, for successful biological evolution on a planet, the luminosity of its parent star must be constant for at least this long. Thus we see from the table that only those main-sequence stars at and below spectral type *F* can support life. Others evolve too fast and do not maintain constant luminosities long enough.

A second limitation on the development of life on a planet is its star's ability to warm up a large space around it. Stars are fireplaces in the cold and dark of space, each having a region of propitious temperature in which life may develop and survive. It is evident, for example, that the habitable zones of cool stars of spectral type *M* are much smaller than that of the sun. Therefore, the chance

MASS	TIME-SCALES IN BILLIONS OF YEARS		CHARACTERISTICS ON MAIN SEQUENCE		
(Sun = 1)	*Gravitational Contraction*	*Main-Sequence Stage*	*Spectral Type*	*Radius (Sun = 1)*	*Luminosity (Sun = 1)*
17.0	0.00012	0.008	*B0*	9.0	29,000
6.3	0.0011	0.08	*B5*	4.2	980
3.2	0.0041	0.4	*A0*	2.8	100
1.9	0.022	2	*A5*	1.51	12.0
1.5	0.042	4	*F0*	1.25	4.8
1.3	0.056	6	*F5*	1.24	2.7
1.02	0.094	11	*G0*	1.02	1.2
1.00	0.11	13	*G2* (Sun)	1.00	1.0
0.91	0.14	17	*G5*	0.92	0.72
0.74	0.23	28	*K0*	0.74	0.35
0.54	0.60	70	*K5*	0.54	0.10

*ED. NOTE: For a detailed description of a star of solar mass contracting to the main sequence, see "Early Solar Evolution," Robert R. Brownlee and Arthur N. Cox, SKY AND TELESCOPE, May, 1961, page 252.

of finding a planet revolving permanently inside the habitable zone of an *M* star is less than for somewhat hotter stars. However, *M*-type dwarfs are far more numerous than any other single spectral type, and the total number of them supporting life may be appreciable.

Combining the previous two arguments, we conclude that intelligent life has the highest chance of being found in the vicinities of stars of medium temperature, like the sun. A further limitation applies to binary and multiple systems, which constitute about one third of all stars. A planet associated with a binary may or may not have a stable orbit, and in the latter case could wander out of the habitable zone and destroy life that might have developed earlier.

As for a life-supporting planet itself, one of its most important qualifications is maintenance of an atmosphere suitable for the chemical processes of living beings. An atmosphere makes possible the existence of water or other substances in liquid form on the planet's surface; it is simply inconceivable that living organisms can be maintained without the aid of some substances in liquid form.

The earth holds its air because its gravitational attraction prevents gas molecules, which are in a state of thermal motion, from escaping. The moon and Mercury are devoid of atmospheres partly because of their smaller surface gravities; hence, a larger planet is required.

But it is not advantageous to the emergence of life, especially of a high form, if the planet is too big. Since the most abundant element in the universe is hydrogen, a newly formed planet must have a high percentage of it, particularly in its outer envelope, because of hydrogen's light weight. In other words, we expect a new planet's atmosphere to be chemically in a reducing state. As A. I. Oparin has pointed out, life may first appear under reducing conditions, but it seems unlikely that life of a high form would emerge under such a dominantly hydrogen atmosphere.

My tentative conclusion is based upon the energy metabolism of living beings. In an oxidizing atmosphere, like the earth's, the combustion of glucose,

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O,$$

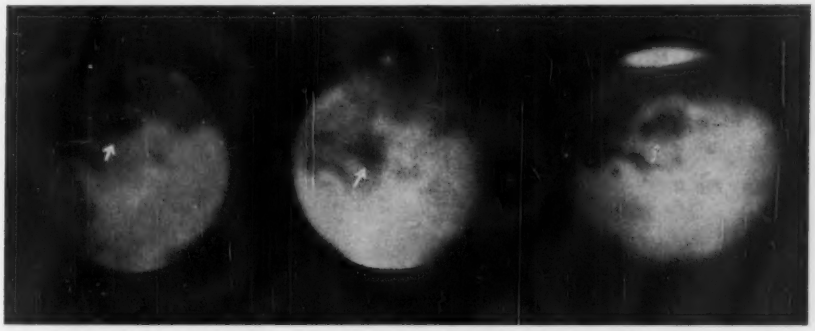
which supplies most of the body's needs for energy, yields about 700 kilogram calories of free energy per mole. On the other hand, in a reducing atmosphere the free energy has to be derived from fermentation of glucose to ethyl alcohol and carbon dioxide, according to

$$C_6H_{12}O_6 \longrightarrow 2\,C_2H_5OH + 2\,CO_2,$$

which amounts to only about 60 kilogram calories per mole.

Consequently, under reducing conditions a living being has to consume more than 10 times as much food as in an oxidizing environment in order to derive the same amount of free energy. Therefore, it is doubtful that a mind such as man's would appear through evolution in a reducing atmosphere, because living beings would be too preoccupied with seeking food.

If hydrogen must first escape from the air before a high form of life emerges, the planet must not be too large. Plausible values for the radius would be between 1,000 and 20,000 kilometers, which includes the moon and Mercury. The former could hold air if its density were high, and the latter would have a suitable atmosphere if its distance from the sun were greater.



The changing dark markings of the planet Mars have suggested to some astronomers the presence of life. In these three Lowell Observatory photographs, taken by E. C. Slipher in 1911, 1926, and 1939, the white arrow points to Solis Lacus, a dark area remarkable for its variations.

The problem of life on other worlds is ultimately related to the formation of the complex molecules that are essential to life processes. Life on the earth, as we all know, depends upon carbon-containing molecules and on water. The fundamental question of bioastronomy is whether living beings elsewhere must also depend on the carbon bond, with water as a solvent. Although a definite answer cannot be provided, I have several arguments in favor of an affirmative one.

From what other element can complex molecules be built? A glance at the periodic table shows silicon, located directly below carbon, to be a likely candidate. Indeed, silicon is largely responsible for the great variety of molecules found in the earth's crust. However, silicon appears to have a higher affinity for fluorine and other halogens than for hydrogen. While its cosmic abundance is as much as one fifth that of carbon, the percentage of halogens in the cosmos is negligible compared with hydrogen. As a result, complex compounds of silicon have much less chance to form than do those involving carbon.

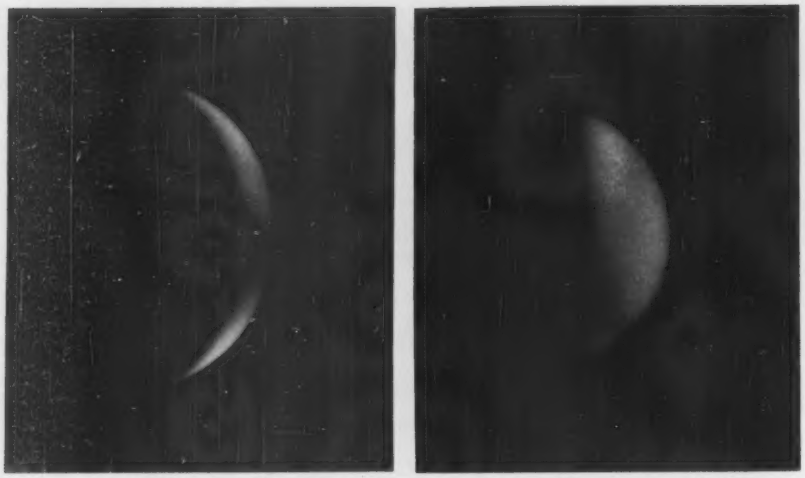
There are several empirical results favoring carbon as an essential life constituent. M. Calvin and his associates made the first successful experiment in prebiological chemistry when they obtained formaldehyde and formic acid in a cyclotron from a mixture of carbon dioxide and water. In 1953, S. L. Miller found that the amino acids — the building blocks of proteins — are formed, together with other organic compounds, when an electric discharge is passed through a mixture of methane, ammonia, and water vapor, in concentrations approximately equal to those given by H. C. Urey for the primitive atmosphere of the earth.

Calvin also discovered organic compounds in meteorites. Very recently B. Nagy, D. J. Hennessy, and W. G. Meinschein detected paraffinic hydrocarbons, closely akin to those found on earth in living matter, in a fragment of a stony meteorite that fell in France nearly a century ago. They believe this to be the first empirical evidence for the existence of life beyond our own planet. Such an interpretation has not been unanimously accepted by authorities on this subject. However, if the meteorite's hydrocarbons are not due to contamination, they indicate definitely that the formation of organic compounds is not limited to the surface of the earth, although the mechanism of formation may be debated for a long time to come.

All these results suggest that complex compounds of carbon can be formed easily from inorganic substances when conditions are suitable. We may not be seriously wrong if we assume that life everywhere in the universe depends on carbon compounds.

The question of life elsewhere in the solar system is no longer as speculative as it was even a decade ago, and in 10 years we may have definite proof concerning the present existence of living beings on other planets. But if no life is found, it does not prove that none ever appeared — such proof requires actual excavation of a planet's surface, which may take a few decades to achieve.

Mars is most frequently mentioned as a possible former or present abode of life. Despite its small gravitational attraction (with only 10 per cent of the earth's mass), its surface gravity is 37 per cent of ours and it retains an atmosphere. There is no hydrogen or helium; none is expected. Spectroscopic observations show carbon dioxide is present, but the search for oxygen has been negative. Mars' atmosphere contains less than 1/1,000 as



The delicate dusky markings of the cloud-covered planet Venus are well shown in these photographs taken by H. Camichel with a 15-inch telescope at Pic du Midi Observatory in France. The narrow crescent (left) was recorded on October 3, 1943, the other view on the 6th of the following month. Venus' high surface temperature makes it ill-suited as an abode of life.

much oxygen as the earth's, yet there is doubtless much nitrogen.

Although spectroscopic observations have failed to detect water vapor on Mars, its presence may be indicated by the seasonal variations of the polar caps. However, the physical nature of the polar caps is still debatable. Some observers consider them to be made of ice, but others, like C. C. Kiess and his collaborators (SKY AND TELESCOPE, June, 1960, page 469), explain the caps as solid nitrogen tetroxide.

The temperature of Mars' equatorial region can reach a maximum of about 30° centigrade, but in general is lower than on Earth. Since not much water exists in the Martian atmosphere to keep heat from radiating away into space at night, the temperature probably reaches as low as −100° C. Whether life can be maintained under these conditions has interested astronomers for a long time.

Dark green areas in the equatorial regions suggest that plant life of some form is present on Mars. The color and shade of these markings change with the seasons in a way that indicates the growth and decay of vegetation (darker in spring and lighter in autumn). Because of the very severe climate, no higher terrestrial plants could survive. However, special kinds, such as lichens, might live. A lichen is a symbiotic plant composed of two different organisms: fungus and alga. These can flourish together under conditions that would be fatal if either had to meet them alone.

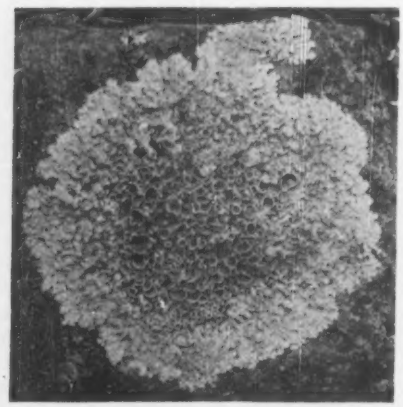
The fungus, which does not perform photosynthesis, derives food from the alga, which does. But the fungus helps maintain the water supply necessary for growth of the alga. Consequently, this symbiotic plant occurs all over the earth, enduring many kinds of extreme climate, from burning deserts to freezing mountaintops. However, it is not necessarily lichens themselves that we observe in the dark-green areas of Mars.

Rather, we wish to emphasize here that the severe climate on Mars does not exclude the possibility of the maintenance of life there. Indeed, observations by W. M. Sinton strongly imply that an infrared absorption band characteristic of many organic compounds is present in the Martian spectrum, which strengthens the belief in some form of vegetation on that planet.

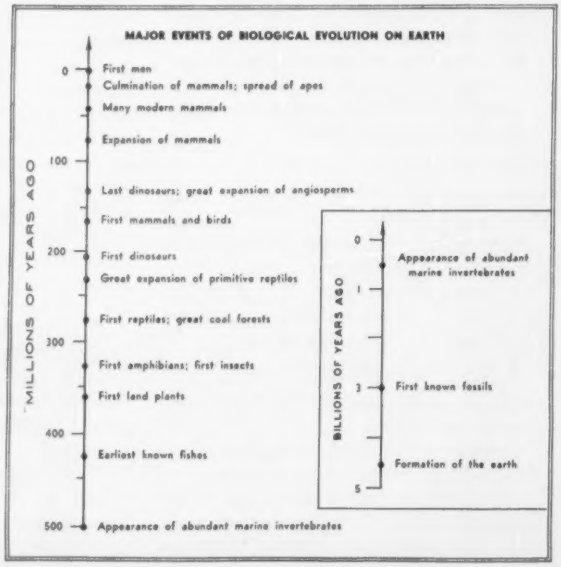
Because Mars lacks oxygen, most astronomers agree that we should not expect to find a high form of life there, and I personally believe this conclusion is probably right. But there is the unlikely possibility that intelligent beings might have existed, or still survive, on Mars. This view does not need the support of the canals, whose interpretation has aroused much controversy. But since Mars' gravity is smaller than the earth's, it was easier for hydrogen to dissipate, and biological evolution could have started earlier on the red planet than here. It is not inconceivable that intelligent beings emerged on Mars millions of years ago. One might object that the rate of evolution would be slower because chemical reactions would occur less rapidly at the low Martian temperature. On the other hand, the development of the human brain may have been completed during the glacial ages here on earth.

The other neighbor of the earth is Venus. Carbon dioxide is abundant in its atmosphere, and water vapor has recently been established by John Strong, but oxygen has never been detected. There are extensive clouds that prevent us from seeing the planet's actual surface, and we can only measure the composition of the upper atmosphere. The clouds themselves probably consist of water droplets or ice particles.

Microwave observations of Venus by C. H. Mayer and his coworkers yield a temperature of more than 300° C. As Carl Sagan has pointed out, the high temperature of the planet is consistent with an abundance of carbon dioxide and water vapor below the clouds. Both these substances produce a very efficient greenhouse



Left: The ability of lichens to live in extreme environments has made them a favorite subject for astrobiological theories. This picture of the lichen Parmelia is reproduced from C. L. Wilson's "Botany," Dryden Press.



Right: The author's chart of the major events in the evolution of life on our planet. The compressed scale (inset) shows some very early events in the earth's history.

effect, letting visible sunlight pass through but preventing infrared radiation from going out. Hence Venus' surface temperature probably reaches such a high value that life is impossible there.

The existence of life on other bodies in our solar system cannot be categorically denied. However, because of their chemically reducing atmospheres and low temperatures (or very high, for Mercury's sunlit side), life must be very primitive, if present at all.

Elsewhere in the universe, the fundamental problem is the existence of planets. Are stars always accompanied by some smaller bodies? We don't have a definite answer, because of observational difficulties. No earth-bound telescope could detect a planet of Jupiter's size even if it were associated with the nearest star, for the planet would be lost in the glare of the star's light. However, as Nancy G. Roman has suggested, a telescope installed in an artificial satellite would suffer much less from scattering of starlight in the earth's atmosphere and might be used for such a search.

What theoretical reasoning can be applied to this problem? Some 30 years ago astronomers felt that our solar system was formed when the sun encountered another star. Since the average distance between two neighboring stars is very large, a close encounter of this kind is a very rare event, producing only one planetary system among many millions of stars. But it has since been shown that the collision theory of planet formation is untenable.

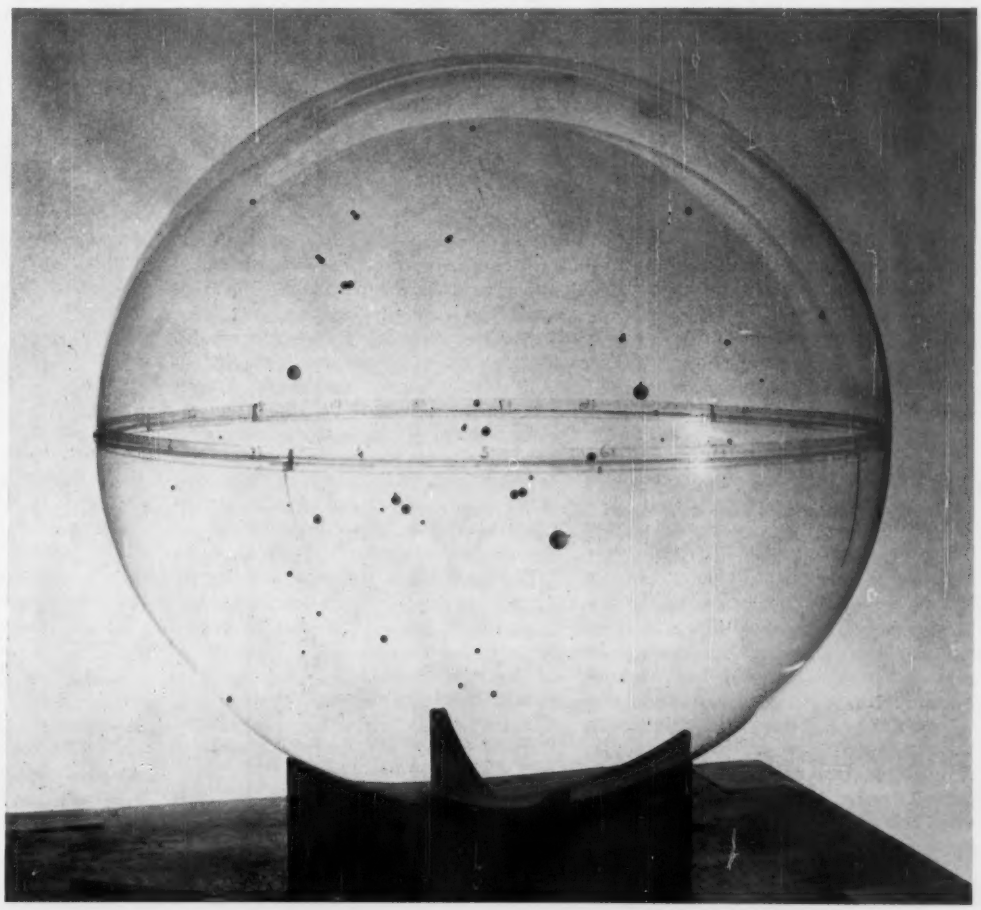
Astronomers are now convinced that planets form from dust and gas that is either the remnant in the process of star formation or that has been acquired from the interstellar medium. If the cloud is massive enough, another star could be formed instead of planets. Thus, binary and planetary systems have apparently the same origin, and they have other properties in common.

According to G. P. Kuiper, the average separation of all components in binary systems that have been studied is about 20 astronomical units, roughly the mean distance of the major planets from the sun. Also, there is wide range in the ratio of masses of binary star components, with a few as small as 10 times the ratio of Jupiter's mass to the sun's. Unseen companions with masses about 0.01 that of the sun have been found by K. A. Strand (61 Cygni) and Sarah Lee Lippincott (Lalande 21185). Since binary stars are very numerous, planetary systems should also occur frequently.

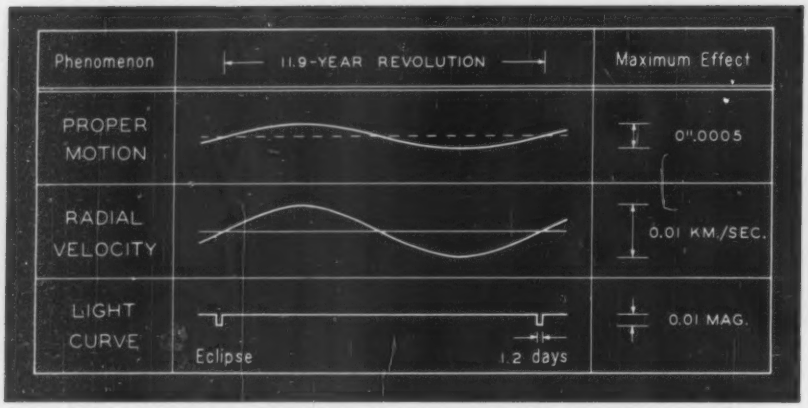
We can also make, heuristically, a prediction regarding the stars that have a good chance of possessing planets. Years ago Otto Struve pointed out that the rapid rotation of early-type main-sequence stars did not occur in classes later than *F5*. In other words, the average angular momentum per unit mass of main-sequence stars suffers a conspicuous discontinuity at this spectral subdivision. A reasonable possibility to explain this is that planetary systems are formed around stars of later spectral types, the unobservable planets absorbing the excess angular momentum in each case.

The available evidence, therefore, suggests that most single stars on the main sequence between *F5* and perhaps *K5* have a good chance of supporting life of an advanced form on their planets. Only a few per cent of all stars fall in this range. Within 16.3 light-years (five parsecs) of the sun, there are 58 other individual stars, five of which are unseen companions. Of 26 single stars in this group, only two besides the sun fall within our limitations for supporting life: Epsilon Eridani, a *K2* dwarf, and Tau Ceti, a *G4* dwarf.

Of course, the actual chance of intelligent life appearing is less than a few per cent. Even if the size of a planet revolving within a habitable zone is right, its surface topography might not be. If the entire surface were water covered, for instance, a civilization like ours could not develop. Taking everything into consideration, I venture to state that no



This Sproul Observatory model made by Sarah Lee Lippincott shows the arrangement in space of all the stars known to lie within 16 light-years of the sun, which is at the center. The plexiglass sphere is 36 inches in diameter, and the distance scale is one inch per light-year. Wooden beads are used to represent the stars, with Sirius (right below center) the largest. To the right above center is Procyon, shown, like Sirius, with its white-dwarf companion. The large star at the left is Altair. Among these stellar neighbors there are 53 visible stars, including Tau Ceti and Epsilon Eridani which satisfy the author's criteria for possibly having planets where intelligent life may exist. These two stars were selected for special scrutiny in the Project Ozma attempt to detect extraterrestrial radio transmissions. Photograph from Sproul Observatory of Swarthmore College.



Three kinds of observational tests are presented for the detection of a planet similar to Jupiter revolving around a solar-type star 32 light-years distant from us. Even at best, the maximum effects (right) are very minute.

more than one to two per cent of stars may have at one time or another supported intelligent life. On this basis, there are within 1,000 light-years a few thousand stars around which life of this nature could appear.

For us on earth, a most interesting question is whether or not intelligent life exists elsewhere right now. What is the chance of finding extraterrestrial contemporaries? No one dares guess how long our civilization will endure. Granted that man does not destroy himself, he still has to face natural calamities, such as a recurrence of the ice ages. Will man's tendency to overspecialization bring about his downfall? I incline to believe that the lifetime of a technological civilization occupies only a very small fraction of the entire period of biological evolution. If so, two such civilizations in different worlds would scarcely be simultaneous.

An interstellar journey will not be within our means for a long time to come. At the speed of artificial satellites that we have launched so far, it would take hundreds of thousands of years to cover the 10 light-years of distance to Epsilon Eridani or Tau Ceti. This leaves us with only radio communication as a possible means of contacting other intelligent beings. This problem has been treated in detail in an article on Project Ozma, by Frank D. Drake of the National Radio Astronomy Observatory, in SKY AND TELESCOPE for January, 1960 (page 140). So far, Project Ozma observations have given negative results.

It is generally agreed among radio scientists that the best frequency to employ is that of the 21-cm. neutral hydrogen line. It has been suggested that the value of pi, or the fine structure constant, or any other dimensionless constant, be transmitted in order to distinguish our signal from natural sources of radio noise. I personally think a great effort of this kind inadvisable, however fundamental the constant might be.

Instead, I suggest using simple numbers: 1, 2, 3, each represented by the corresponding number of dots. They are as good a sign of intelligence as any physical or biological constant. Then we could proceed to introduce the concept of equality and other algebraic symbols (as P. Morrison has also proposed). This can be done by coding such symbols and repeating a large number of examples, just as arithmetic is taught to children. At this stage the binary, decimal, or some other number system may be introduced, and finally the x, y concept of locating a point on a plane. Once this is established, a means for interchanging information follows easily.

While the chances of success in receiving intelligible signals from outer space are extremely small, even during a long search with larger and larger radio telescopes, it is worth trying because of its fundamental importance in understanding the nature of living beings and its impact on our philosophical beliefs.

ASTRONOMICAL SCRAPBOOK

ALGOL AND SCIENTIFIC CONSERVATISM

IN THE YEARS 1879-80, a now-obscure British physicist, David Hughes, demonstrated a novel experiment before leading scientists of the Royal Society, including its president W. Spottiswoode and Sir George Stokes. Hughes used a spark transmitter to produce signals that were detected 500 yards away by a coherer connected to a telephone. The distinguished spectators were unaware that they were witnessing a pioneer demonstration of radio, seven years before Hertz and two decades before Marconi. Instead, the committee decided that the effects were due to electromagnetic induction.

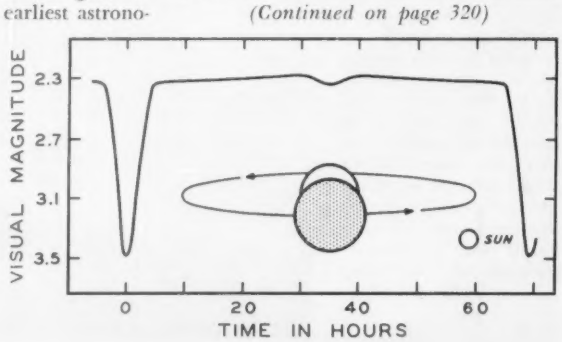
This episode is difficult to explain, for physics had developed to the point where the time was ripe for radio to emerge. In many other cases, the climate of scientific opinion was clearly not yet ready for the reception of some new idea. It is understandable that a novel hypothesis may through its very novelty be beyond the powers of observational test, or too isolated from other knowledge to attract study by theoreticians. Hence the idea may have an obscure currency for many years before a timelier announcement gains general scientific acceptance.

Astronomical history offers many examples of premature discovery. Such modern concepts as galactic rotation and interstellar absorption were already being discussed a century ago, and a method of measuring the radial velocities of stars had appeared in print before 1800.

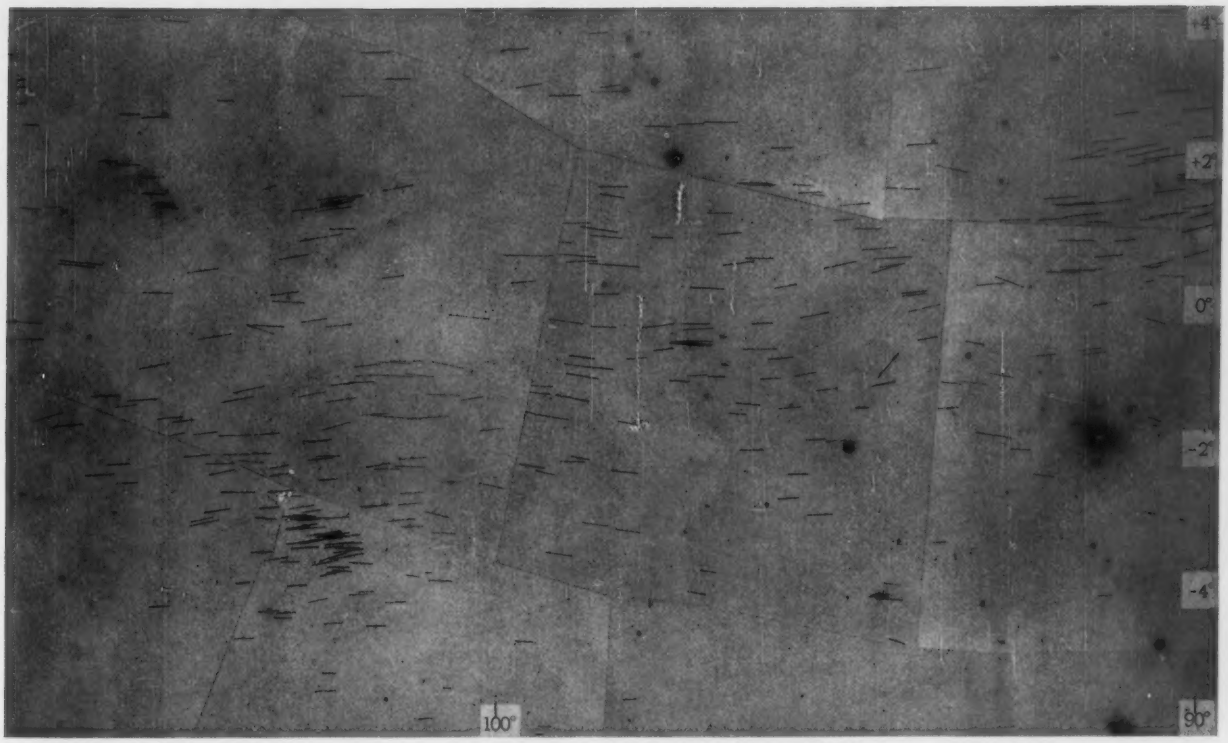
The story of the variable star Algol brings in the names of several astronomers as prophets before their time. The first man known to have noted that Beta Persei is upon occasion fainter than normal was Geminiano Montanari of Bologna, in 1667. He was one of the earliest astronomers to be interested in variable stars, at a time when the only known representatives were Mira and a few novae. Perhaps the foreignness of the notion of short-period variables was one reason why no further attention was paid to the star.

In fact, the variability of Algol had to be rediscovered in 1782 by the English amateur John Goodricke, an 18-year-old deaf-mute. His systematic observations soon showed the periodic nature of the light changes, a temporary decrease in brightness occurring every 69 hours. In reporting these results to the Royal Society, Goodricke advanced two explanations: "If it were not perhaps too early to hazard even a conjecture on the cause of this variation, I should imagine it could

(Continued on page 320)



A modern light curve of Algol shows the nature of its light variations. Below, the relative dimensions of the two components are given, with the sun for comparison. The deep eclipse occurs when the bright star is behind its larger and fainter companion.



On a negative print of a portion of the northern Milky Way, U. S. Naval Observatory astronomers have indicated the polarizations for many stars. The orientation and length of each line indicate the direction and relative degree of polarization of the star's light, respectively. Note that most lines are nearly horizontal (parallel to the galactic equator). The dark image at the right is the bright star Gamma Cassiopeiae, and the close-packed lines at lower left are for stars in the Double Cluster of Perseus. The vertical and horizontal scales are marked in galactic latitude and longitude. This is part of a mosaic from the Naval Observatory "Publications," and is based upon blue plates of the 48-inch Schmidt telescope, taken for the National Geographic-Palomar Observatory sky survey.

Why Is Starlight Polarized?

OTTO STRUVE, *National Radio Astronomy Observatory**

DURING the past 12 years I have written nearly 150 articles for this magazine, quite frequently discussing more or less controversial problems, and occasionally presenting views of astronomers which diverge from those held by the majority. In doing so, I have sometimes been severely criticized by scientists who supported the conventional ideas, and at the same time I have been reprimanded by the authors of debatable concepts who believed their work had not been properly described.

When I write about controversial hypotheses, it is because great scientific advances are often forged in the heat of debate, but I do not necessarily believe the new ideas are correct. Limitations of space and the technical level of presentation often make it impossible for me to include all the arguments of the original authors. Hence, astronomers who disagree strongly with ideas presented here should read the original technical contributions instead of depending solely on my abbreviated and simplified versions in SKY AND TELESCOPE, and should direct their criticisms to the original authors.

A case of this kind is my November, 1960, article, which has caused considerable discussion. Recently, Professor B. A. Vorontsov-Velyaminov wrote me that he had long ago expressed the opinion that the radio source Cygnus A is not a pair of colliding galaxies, several years before the work of I. S. Shklovsky which was described by me.

This month we consider another highly controversial paper, by the German astronomer G. Thiessen. Entitled "On the Polarization of Starlight, the Radiation of the Stars, and Comments on Galactic Structure," it appeared early this year as a publication of Hamburg Observatory.

The story of Thiessen's subject goes back about 13 years, when W. A. Hiltner and J. S. Hall discovered that the light from many distant stars is partially polarized. Their early work was described briefly in my third SKY AND TELESCOPE article, "Polarization of Starlight," in the September, 1949, issue, page 274. At that time and since, it has been generally believed that the Hiltner-Hall polarization is caused by interstellar matter, but Thiessen attempts to prove that the effect arises in the stellar atmospheres themselves, or in their immediate vicinities.

An electromagnetic wave can be regarded as having two mutually perpendicular electric and magnetic components, each also perpendicular to the direction of propagation. The electric component is usually the more important in interactions with matter, and henceforth will be meant in this article when we discuss the plane of vibration of a beam of light.

In ordinary light, the direction of vibration and its phase are constantly changing, in such a way that every direction and phase of oscillation is equally probable. At any instant the vibration has a definite direction, which could be

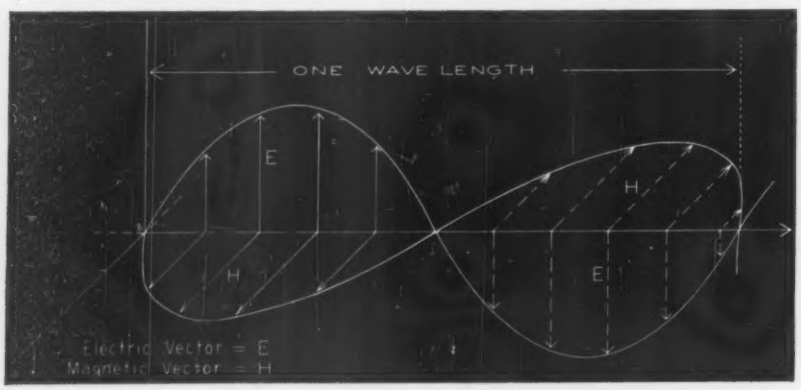
*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.

The Double Cluster in Perseus, about 7,000 light-years away, consists of twin stellar groups. In this photograph, with south upward, h Persei is the cluster at the left, with Chi Persei at the right. Star-poor areas in the surrounding Milky Way indicate veiling by interstellar dust clouds, which partially obscure the Double Cluster. G. Thiessen's new theory of the origin of polarization in starlight is largely based upon observations of stars in h and Chi Persei.

determined if an observation were possible within 10^{-8} second. In general, experiments take a much longer time and we can only observe that all possible vibrations perpendicular to the direction of propagation occur, distributed in radial symmetry about that direction.

If by natural or artificial means the oscillations are all restricted to parallel planes, the light is *plane polarized*. The direction perpendicular to these, which is devoid of electric energy, is called the plane of polarization.

The general case of *elliptical polarization* arises whenever the resolved components have a constant phase difference. A special case of this is *circular polarization*, when the components have equal amplitudes and the phase difference is an odd multiple of 90 degrees. Another special case is *linear polarization*, with the two components in phase.



The electric and magnetic vectors of a wave of electromagnetic radiation are visualized as equal in amplitude and at right angles to each other.

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From this and other observations, both Hiltner and Hall reached the conclusion that such polarization does not arise in the stars themselves, but is caused by suitably oriented grains of interstellar matter. Since that time, the phenomenon has generally been described as interstellar polarization.

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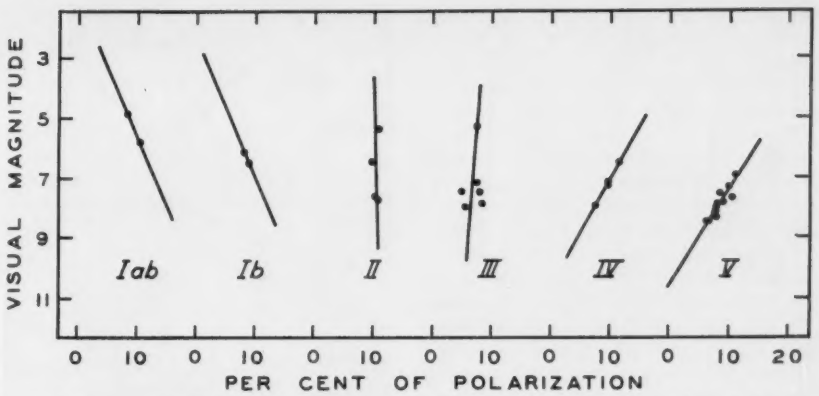
Polarization in the light of southern stars was measured by Elske v. P. Smith with the 60-inch reflector and 13-inch refractor of the Boyden Observatory in South Africa. Combining the results of all three observers, Hall in 1958 published a catalogue of 2,592 stars that had been measured polarimetrically. The largest percentage of polarization in that list is 10, for an 11th-magnitude star in Cygnus.

How could the light from a distant star become polarized in passing through interstellar space? The basic problem was to provide for preferential orientation of spindle-shaped interstellar particles. T. Gold suggested differential motions of gas and dust, while L. Spitzer, Jr., and J. W. Tukey assumed that the particles were ferromagnetic and were lined up by an interstellar magnetic field of the order of 10^{-3} or 10^{-4} gauss. A third theory, and the one that has found almost universal acceptance, is due to L. Davis, Jr., and J. L. Greenstein. They proposed that the particles are paramagnetic and rotate rapidly in a 10^{-5}-gauss magnetic field whose lines of force are parallel to the galactic plane.

However, Thiessen points out that some of the observational results seem inconsistent with an interstellar theory. For example, G. Münch and W. W. Morgan had found in several groups of *O* and *B* stars a strong degree of polarization that appeared to be uncorrelated with interstellar absorption. On the other hand, Hiltner had established in the cluster M29 that there was a linear relation between absorption and polarization, with zero polarization occurring for stars with 2.6 magnitudes of absorption. In another article, Hiltner reported two regions of the sky where no relation existed between polarization and distance. Similarly, Hall discovered that in stellar associations at very different distances from us there are stars having nearly the same degree of polarization.



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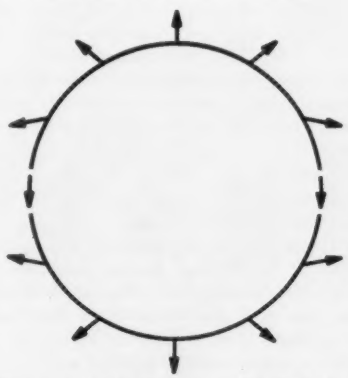

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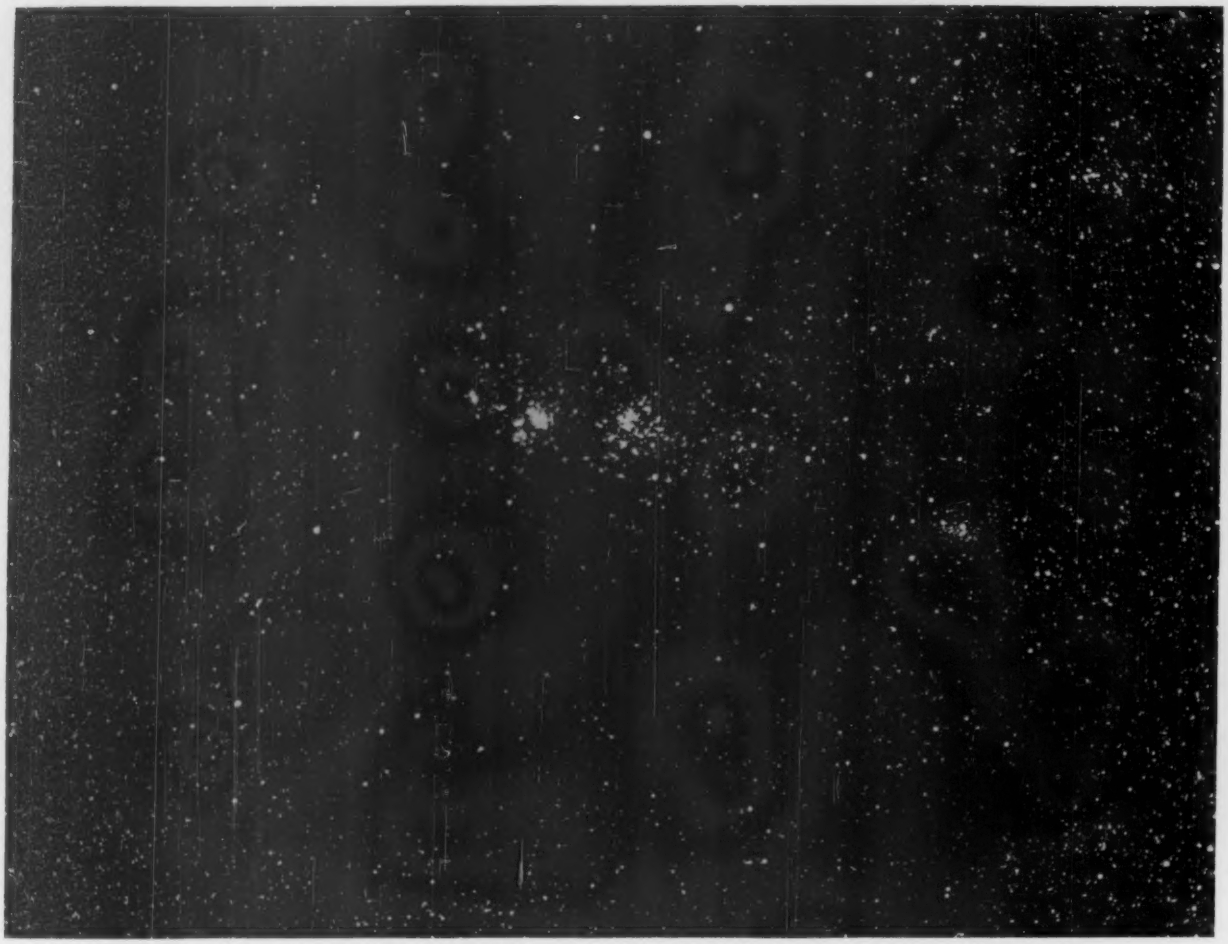

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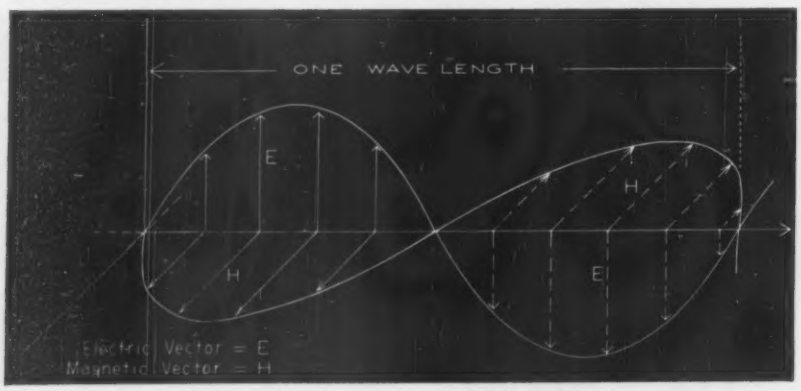

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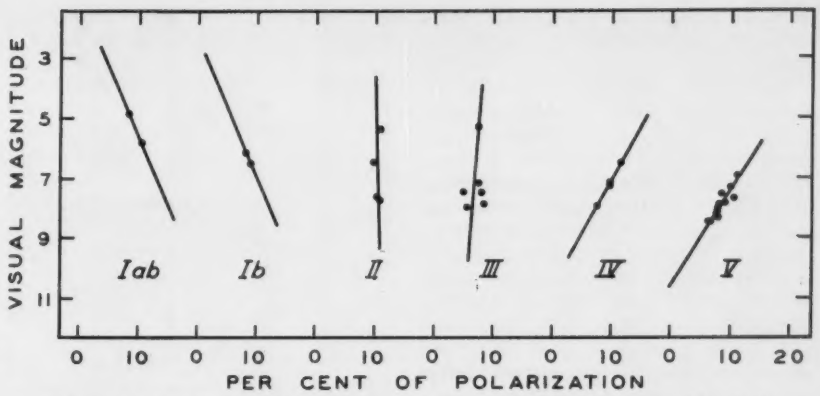

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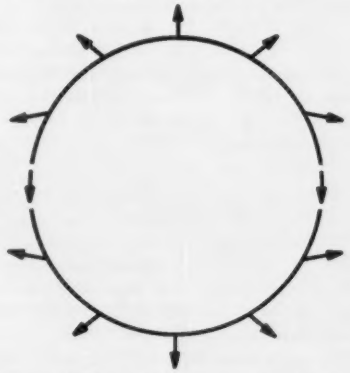

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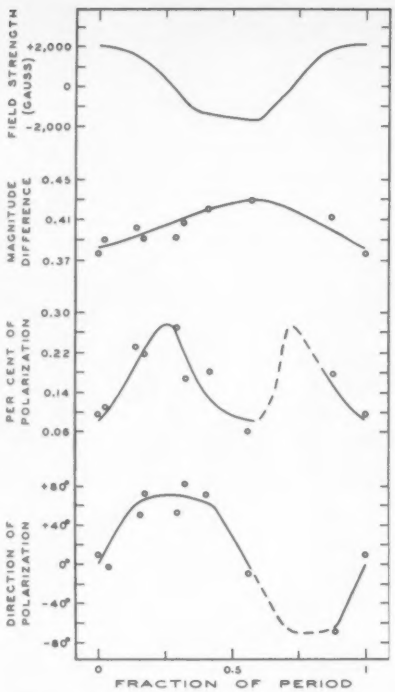
of a foundation of astrophysics needs thorough testing before it can be accepted.

Synchrotron radiation in a stellar atmosphere may occur, Thiessen suggests, because of the ejection of very fast electrons outward from the star, in a dipole magnetic field. (See sketch on page 319.) If the star's magnetic axis were in the line of sight, no polarization would be observed, because of simple symmetry considerations. The polarization would be a maximum if the magnetic axis were at right angles to the line of sight. Since the observations of Hiltner, Hall, and others indicate that the electric vector for stars in all parts of the Milky Way is approximately parallel to the galactic plane, Thiessen concludes that the vast majority of stars have their magnetic axes oriented perpendicular to this plane. At present, there is no observational material for an independent test of this hypothesis.

But it is possible to check Thiessen's further conclusion that in all probability the magnetic axes and rotational axes of stars approximately coincide. From this he argues that most stars rotate with their equators parallel to the galactic plane. This problem has been investigated several times. My own early work on stellar rotation failed to show any preferential orientation of the rotational axes of stars, and I believe this result has been on the whole confirmed by other investigators. Clear-cut answers are not very easy to obtain, because even for objects of similar spectral type selection effects favor high-luminosity stars in and close to the galactic plane, while at high galactic latitudes the observations are chiefly of nearby main-sequence stars.



Four different kinds of variability in the magnetic star HD 71866. Thiessen finds that the degree of polarization has two maxima in each 6.8-day cycle.

A good deal of careful work has been done on the orientation in space of the orbital planes of visual and spectroscopic binary stars. The best statistical studies have shown no preferential orientation. The origins of binary systems and of stellar rotation appear so closely related that the same tendency toward uniform orientation, or the lack of it, would be expected in both cases. No such tendency has been found. Large-scale motions do occur preferentially in the galactic plane, but perhaps the small turbulent eddies that ultimately produce rotating single stars, binaries, and possibly clusters, have completely lost their systematic orientations.

There is more to Thiessen's work than the items I have mentioned. The last section of his report describes polarization measurements of the magnetic star HD 71866 which he made with the 24-inch Bergedorf refractor. Horace Babcock's observations had shown that its magnetic field varies between +2,000 and −2,000 gauss in a 6.8-day period. Photometric measures indicated that the brightness varies by a few hundredths of a magnitude in the same period. Now Thiessen finds that the polarization also changes in a 6.8-day cycle, maximum polarization occurring when the magnetic field is approximately zero. It would be of great value to repeat these observations, in order to establish whether in this star at least a part of the polarization is stellar instead of interstellar.

I am indebted to Mrs. M. J. Wade for assistance in the preparation of this article.

ASTRONOMICAL SCRAPBOOK

(Continued from page 316)

hardly be accounted for otherwise than either by the interposition of a large body revolving around Algol, or some kind of motion of its own, whereby part of its body, covered with spots or such like matter, is periodically turned toward the Earth."

Goodricke's binary interpretation was advanced when the existence of binary stars was only conjectural. Christian Mayer of Mannheim Observatory had, a few years earlier, been ridiculed when he announced that certain bright stars were attended by visible satellites. It is well known that William Herschel was very slow to reach a decision that visual binaries existed, a conclusion that he did not publicly acknowledge until 1802. Herschel inspected Algol telescopically and reported it as single even with highest magnification. The tide of astronomical opinion was clearly against the binary hypothesis, and remained so for many years.

But in 1787, Goodricke's paper was studied by a young Swiss, Daniel Huber, who later became professor of mathematics at Basel. He first demonstrated that star spots could not satisfactorily explain Algol's variation. Proceeding to an analysis of the light curve, he deduced that it could result from eclipses of Algol by a dark secondary star whose diameter was 0.71 that of the primary, and distant from it 5.635 radii of the latter. Huber even calculated the average density of Algol as 0.292 that of the sun. This remarkable investigation of Huber's was the first crude solution of the light curve of an eclipsing binary. Disregarded by contemporaries, the paper was forgotten until it was rediscovered a few years ago by the German historian of astronomy, Ernst Zinner.

Independently, a somewhat similar discussion of Algol was carried through by a little-known English clergyman, William Sewell, in 1791. He sent his results to the Royal Society for publication, but their significance went unrecognized and the manuscript was discovered among the archives at Greenwich Observatory only in 1957, by Olin J. Eggen.

It is disconcerting that the correct insight of Goodricke, Huber, and Sewell went for nothing, and that nearly a century was to elapse before their ideas took permanent root. From the viewpoint of 1791, a conservatively minded astronomer could marshal convincing doubts. To him the binary nature of Algol would seem an assumption not capable of being verified observationally. Also, at that time four short-period variables were known — Algol, Beta Lyrae, Delta Cephei, and Eta Aquilae — and the light curves of the last two did not suggest eclipses.

The growth of a favorable climate of opinion came much later. Additional discoveries of Algol-type stars during the 19th century finally suggested that they form a distinct class of variable, and meanwhile visual binaries became familiar objects. Goodricke's hypothesis began to be mentioned more often, by T. S. Aldis in 1870 and by Angelo Secchi in 1877, and four years later E. C. Pickering of Harvard re-explored it theoretically.

The final justification came with H. C. Vogel's spectroscopic observations at Potsdam Observatory in 1889, which demonstrated that Algol's radial velocity varies in the same period as its brightness, with the bright star in the farthest part of its orbit at minimum light, exactly in accord with the eclipse hypothesis.

JOSEPH ASHBROOK

CORRECTION

The caption for the meteor spectrum on page 220 of the April issue should state that the meteor's motion was upward on the page, rather than downward.

NEWS NOTES

MASSES OF SINGLE STARS

Practically all our information about masses of stars has been gained from observations of binary systems, the amount of material in a star being indicated by the orbital motion of its neighbor. Now the Washburn Observatory astronomer R. C. Bless has demonstrated a practical method for finding the masses of isolated stars of spectral class *A*.

His observations consist of photoelectric measurements of brightness at different wave lengths in the continuous spectrum. This was done for 18 *A* stars of known distance, with the aid of the University of Michigan's 24-inch Schmidt telescope. The intensity distribution in a star's continuum depends upon its effective temperature, surface gravity, and chemical composition (which may be regarded as known). Thus Dr. Bless, by comparing the observed distributions with those for model atmospheres calculated by K. Hunger and K. Osawa, was able to evaluate the first two properties.

From the temperature of the star he could calculate what its radius must be to provide the observed luminosity. And from the radius and surface gravity he could compute the star's mass. For example, Vega has an effective temperature of 9,400° Kelvin, a radius 3.2 times the sun's, and 3.0 times the sun's mass.

Good observations should furnish stellar masses to within about 50 per cent by this method, Dr. Bless points out in the *Astrophysical Journal*.

CEPHEID SURVEY

Cepheid variable stars are of great value in charting the structural details of our Milky Way system, for accurate photoelectric measurements of these stars' apparent magnitudes and colors can furnish both distances and the amount of interstellar dust along their respective lines of sight.

A major contribution has been made at Lowell Observatory by three guest astronomers, Harold Weaver and D. Steinmetz from the University of California, and R. Mitchell of the University of Texas. On 61 nights in 1959 they used the Lowell 21-inch reflector for photoelectric brightness measurements of 64 Cepheids in yellow, blue, and ultraviolet light. For 55 stars, enough observations were secured to draw light curves. The results are detailed in Lowell Observatory *Bulletin* 110.

Several of the individual variables reveal noteworthy peculiarities. AP Herculis, whose light curve is reproduced here, is a 10-day Cepheid famous for its exceptionally large changes in period. Three other stars (TU and BY Cassiopeiae, MZ Cygni) show pronounced instability in their light variations. In the case of 11th-magnitude CN Lyrae, a previously reported period of 2.34 days has turned out to be erroneous, and a new study is needed to ascertain the true nature of the variability.

Similar surveys of southern Cepheids had been made from Australian and South African observatories, but comparable work on northern ones had lagged.

AMERICAN ASTRONOMICAL SOCIETY JUNE MEETING

The 108th meeting of the American Astronomical Society will be held at Nantucket, Massachusetts, June 18-21, by invitation of Dr. Dorrit Hoffleit, director of the island's Maria Mitchell Observatory. Hotel reservations at the Sea Cliff Inn, headquarters for the meeting, may be made through her.

In addition to the regular sessions for technical papers, the program will feature the Henry Norris Russell lecture, "Some Characteristics of Galaxies," by W. W. Morgan, Yerkes Observatory. Gerhard Herzberg, National Research Council of Canada, will preside at a special symposium on comets.

MINOR PLANET EPHEMERIDES

The more than 1,600 numbered minor planets would soon become lost if ephemerides ceased to be available. For a few asteroids, such as Ceres, Pallas, Juno, and Vesta, tables exist from which accurate predictions of positions can be made for several decades to come. But the laborious calculation of most asteroid ephemerides has been on a year-to-year basis.

In the United States, work on minor planet orbits and predictions is centered at Cincinnati Observatory, under the leadership of Paul Herget. Recently, Dr. Herget was able to use the NORC computer of the U. S. Naval Weapons Laboratory, at Dahlgren, Virginia, to calculate ephemerides of 53 asteroids up to the year 2000. This enormous task took less than 30 minutes running time on NORC, but preparation of the input data was much more time consuming.

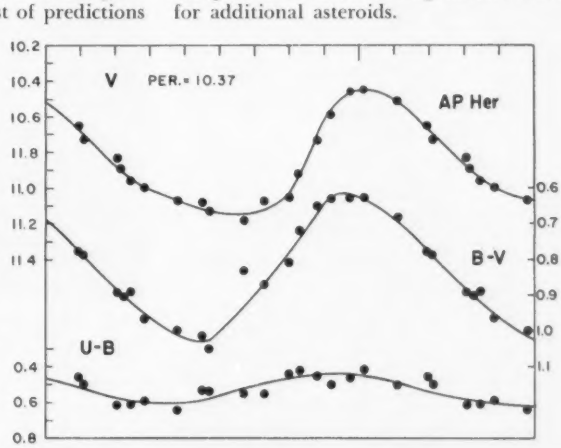
The ephemerides consist of predictions at 10-day intervals of right ascension to 1ˢ and declination to 0′.1, distances from the earth and sun, magnitudes, and various auxiliary quantities. These results were produced on 35-mm. microfilm, copies of which have been deposited at the U. S. Naval Observatory and at minor planet centers in Heidelberg, West Germany, and Leningrad, U. S. S. R. Dr. Herget will be undertaking similar work for additional asteroids.

IN THE CURRENT JOURNALS

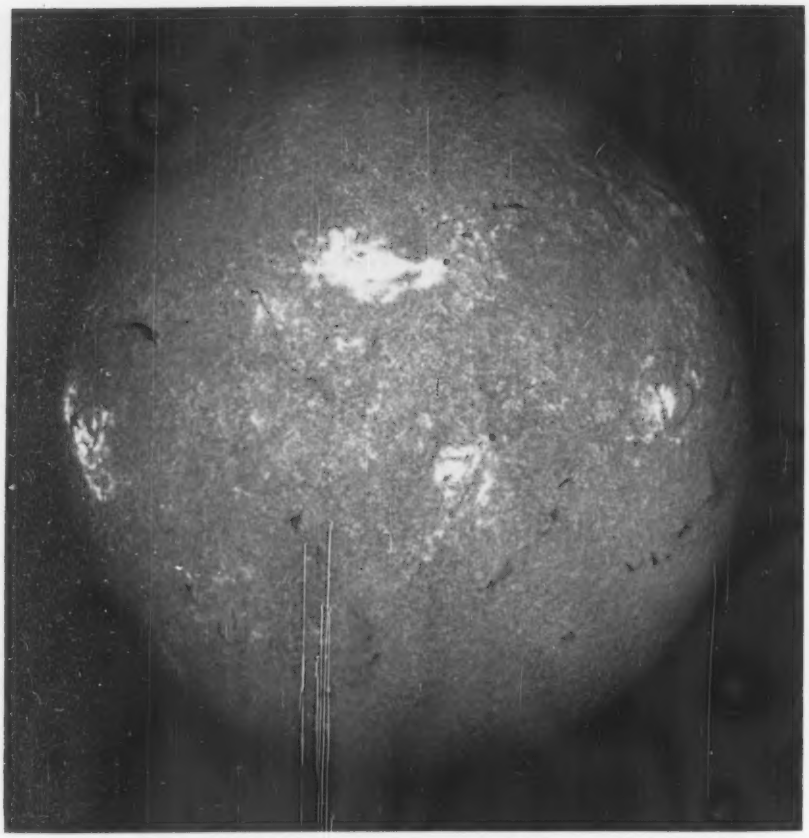
THE PLANET VENUS, by Carl Sagan, *Science*, March 24, 1961. "From the surface of Venus we might see the sun only dimly; the sky would be completely overcast perhaps 90 percent of the time, and the high-altitude white clouds would sometimes appear reddened by dust in the lower atmosphere. The Cytherean atmosphere may be transparent in the near ultraviolet. Hot, arid, calm, and overcast, the surface of Venus appears inhospitable for human habitation at the present time."

SOLAR SPECTROSCOPY IN THE FAR ULTRAVIOLET, by Richard Tousey, *Journal* of the Optical Society of America, April, 1961. "At the beginning of World War II, in spite of much effort, nothing had been learned about the spectrum of the sun beyond about 2900 A. However, the necessary optical techniques were ready; all that was required was a vehicle to carry an instrument to altitudes above the absorbing atmosphere of the earth."

THE SIZE OF THE SOLAR SYSTEM, by James B. McGuire, Eugene R. Spangler, and Lem Wong, *Scientific American*, April, 1961. "From the flight of *Pioneer V* we have obtained what amounts to increased confidence in Rabe's value [of the solar parallax], though not necessarily an improvement on it. We can now be reasonably certain that the astronomical unit is no less than 92,911,000 miles (Rabe's minimum value) and no more than 92,934,000 miles (the maximum from *Pioneer V*). This still leaves a substantial uncertainty of some 23,000 miles."



Photoelectric light and color changes of the Cepheid variable AP Herculis. The horizontal scale is divided into tenths of the 10.37-day period. The top curve is magnitude variation in yellow light. Changes in color are shown by the curves for B — V (blue-minus-visual) and U — B (ultraviolet-minus-blue) magnitude differences. Lowell Observatory chart.



This solar flare of importance 3+ was recorded in hydrogen-alpha light at 14:37 Universal time on November 12, 1960. The white-light picture on the facing page shows the sunspots in the sun's upper part where the flare burst forth. Sacramento Peak Observatory photograph.

Solar Disturbances and Radio Communication Forecasts

JAMES F. BROCKMAN
Boulder Laboratories
National Bureau of Standards
U.S. Department of Commerce

FROM a vast dark sea of gas in the northern half of the sun erupted a brilliant crimson flare, large enough across its base to engulf our earth 20 times. McMath-Hulbert Observatory in Michigan placed a hurried telephone call announcing that a major flare (rated 3+) was in progress. This was the first of a wave of reports to the Fort Belvoir, Virginia, field station of the National Bureau of Standards. The outburst was also observed from the Netherlands, East Germany, Sweden, Alaska, and New Mexico. It was 8:25 a.m. Eastern standard time, November 12, 1960.

Thus began the biggest solar disturbance of recent years. For hours during the geomagnetic storm that followed, long-distance radio communication did not exist over most of the earth, and voltages in power lines on land wavered erratically. The Coast Guard could not contact its weather ships in the North Atlantic, and the orbiting time of satellite Echo I decreased due to heating and expansion of the earth's atmosphere.

James Weldon, duty forecaster at Fort Belvoir, had been expecting a rather uneventful day. From reports of solar activity on November 10th, he had predicted short-wave disturbances for the 12th and 13th, and was waiting to see if these would happen. But now the phone calls and telegrams began pouring in: "Major solar flare . . . short-wave fadeouts in progress . . . major solar noise burst at 200 and 545 megacycles." A few hours later the messages reported: "Relativistic particle increase from solar flare; cosmic ray intensity has been rising for past six hours . . . polar-cap absorption of 10 decibels carried indicator off scale — could be as high as 15 decibels — still in progress . . . earth-current measurements show great disturbance. . . ."

Weldon quickly released a prediction that there would be major interference to short-wave radio within 24 hours. This was almost sure-fire, judging from the telegraphed reports. He also called a Special World Interval to increase scien-

The control room of the World Warning Agency at Fort Belvoir contains (from the left) a teletype unit, a radio direction finder, radio intensity recorder, and an instrument to measure magnetic field fluctuations. Incoming messages bring data on solar and atmospheric activity, those sent warn scientists of expected geophysical disturbances. Unless otherwise credited, all illustrations with this article are from the National Bureau of Standards.

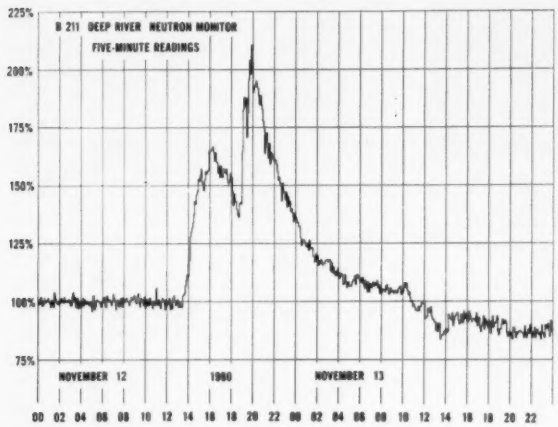
tific observations on a global scale. For the duty forecaster it was the beginning of a hectic week.

Weldon's radio-interference prediction brought immediate telephone calls for special communication forecasts from the U. S. Navy, Army Signal Corps, and Coast Guard; from the Voice of America and the Canadian Broadcasting Co.; from American Cable and Radio and the Radio Corporation of America. Because of the prediction made two days earlier by Weldon, RCA was already communicating with Europe via its mid-Atlantic route (Tangiers). When this second major outburst began, RCA promptly switched to underseas cable.

The Special World Interval speeded up observations by hundreds of scientists around the globe. They measured the height and density of the ionosphere every five minutes instead of every 15; auroral observers were on the alert as far south as Mexico; balloons were launched to record cosmic rays at high altitudes; and ground-level recordings were stepped up. At Fort Churchill, Canada, on Hudson Bay, a discouraged group of American scientists had been considering wrapping up their rockets and returning home, for they had waited weeks to record the effects of a major solar outburst at that latitude. Upon receiving the alert, they sent up a series of rockets and collected a file of excellent data.

Solar flares, which always occur in active sunspot regions, emit strong radiation and spray clouds of ionized particles into space. The various effects on the earth are indicated in the accompanying chart. Some of the particles (called relativistic) travel at nearly the speed of light and may cause an almost immediate increase in the number of cosmic rays reaching the earth's surface. Slower particles, which usually arrive a day or two after the initial flare, interact primarily with the electrified layers of the atmosphere 50 to 300 miles high — the ionosphere. When these layers become sufficiently disturbed, they no longer reflect short-wave radio signals back to earth and long-distance communication is blacked out. The same particles also produce auroras.

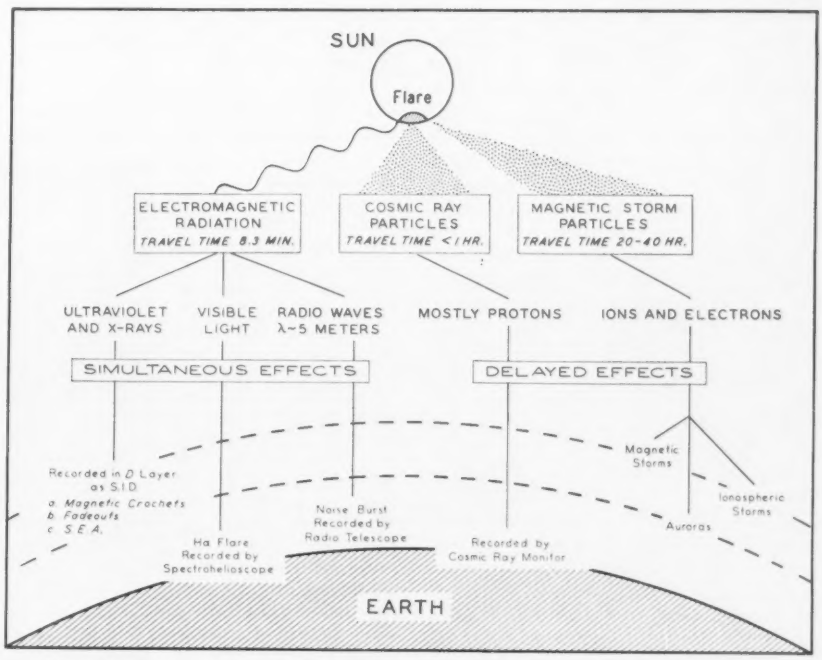
A Mount Wilson Observatory white-light photograph of the sun November 11th, the day before the great flare, which occurred over the large sunspot group.



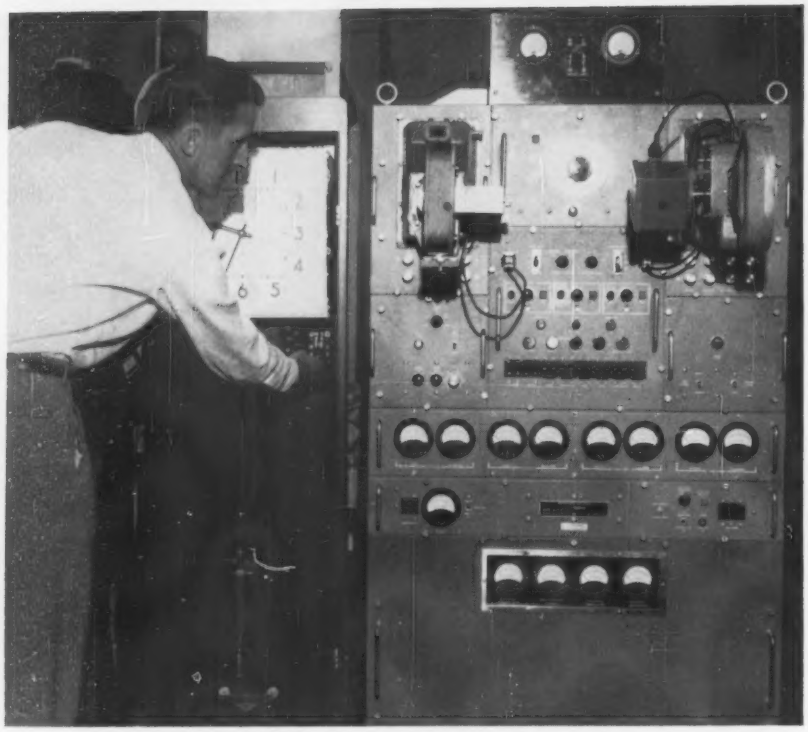
This record of cosmic-ray activity, evidenced by neutrons raining upon the earth's surface, shows the sudden increase that immediately followed the onset of the November 12th flare at 13:25 UT. The peak intensity is more than twice the normal count.

Particles of intermediate energies are believed to cause polar-cap absorption — a communications blackout at certain radio frequencies in a broad area circling the earth's magnetic poles. To varying degrees, all of these particles tend to upset the normal lines of force in the earth's magnetic field.

Lower radio frequencies (longer wave lengths) are reflected by the lower ionospheric layers, higher frequencies by the upper layers, while very short waves pass through to outer space. The National Bureau of Standards sponsors over 20 field stations in the Western Hemisphere that operate ionospheric sounders, which



Effects of a solar flare. Dashed ring indicates the ionosphere. Abbreviations at the lower left stand for Sudden Ionospheric Disturbances and Sudden Enhancement of Atmospherics. After M. A. Ellison, courtesy "Discovery."



At the NBS Central Radio Propagation Laboratory, John Pitts synchronizes an ionospheric sounder with an invar pendulum clock (left), so that the date-time circuits will give the correct relation between soundings and time. This unit can be operated manually or set automatically to take soundings and record "ionograms" of frequencies, intensities, and times.

bounce radarlike signals against the ionosphere to determine the highest frequency that will be reflected by a point directly overhead. These sounders showed that the major effects of the November 12th disturbance, as expected, were concentrated near the magnetic poles.

Point Barrow and Fairbanks, Alaska, for example, had total blackouts, as did Byrd Station, Antarctica, and the south geographic pole. In Washington, D. C., at local noon on November 13th, the maximum frequency reflected at the zenith was four megacycles per second, instead of the 12 megacycles that is normal for that time of year and phase of the sunspot cycle. At Grand Bahama it was 4.5 megacycles and at Natal, Brazil, 9.5, the normal in both cases being about the same as Washington's. However, at Concepcion, Chile, which is just below the magnetic equator, a frequency of 14.6 megacycles — 1.5 higher than normal — could be reflected.

Ionospheric soundings can be used to calculate the heights and densities of ionospheric layers, and can be compared with data recorded during earlier years of similar sunspot activity. From such studies the Prediction Services section of the NBS, headed by W. B. Chadwick, forecasts three months in advance the best radio frequency for communication between any two points on the globe at any particular time of day.

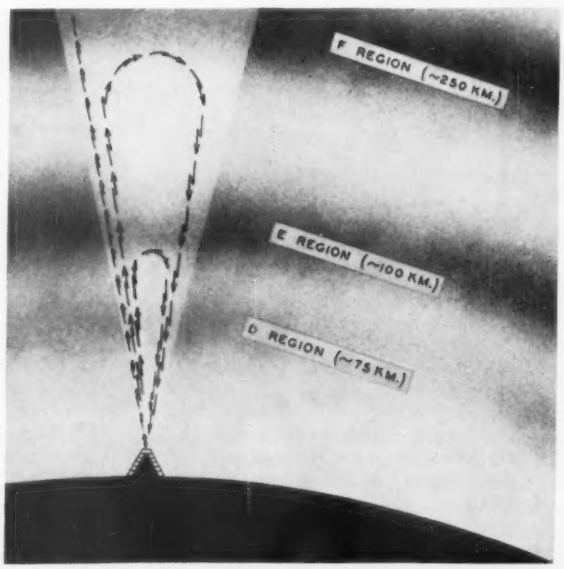
Short-term forecasts — on a weekly, daily, and six-hour basis — are made by the Radio Warning Services section, under J. Virginia Lincoln, which operates three radio warning centers. The predictions are based on up-to-the-minute analyses of radio propagation, solar, ionospheric, and geomagnetic observations from a worldwide network of solar and geophysical observatories.

Forecasts of geomagnetic conditions and monthly summaries of all predictions are made by Warning Services headquarters in Boulder, Colorado. The Radio Warning Centers at Fort Belvoir and at Anchorage, Alaska, predict disturbances in the short-wave communications paths over the North Atlantic and North Pacific areas, respectively. They usually cover the frequency range of two to 30 megacycles, and such paths as New York to London, Washington to Paris, and Anchorage to Seattle or Tokyo.

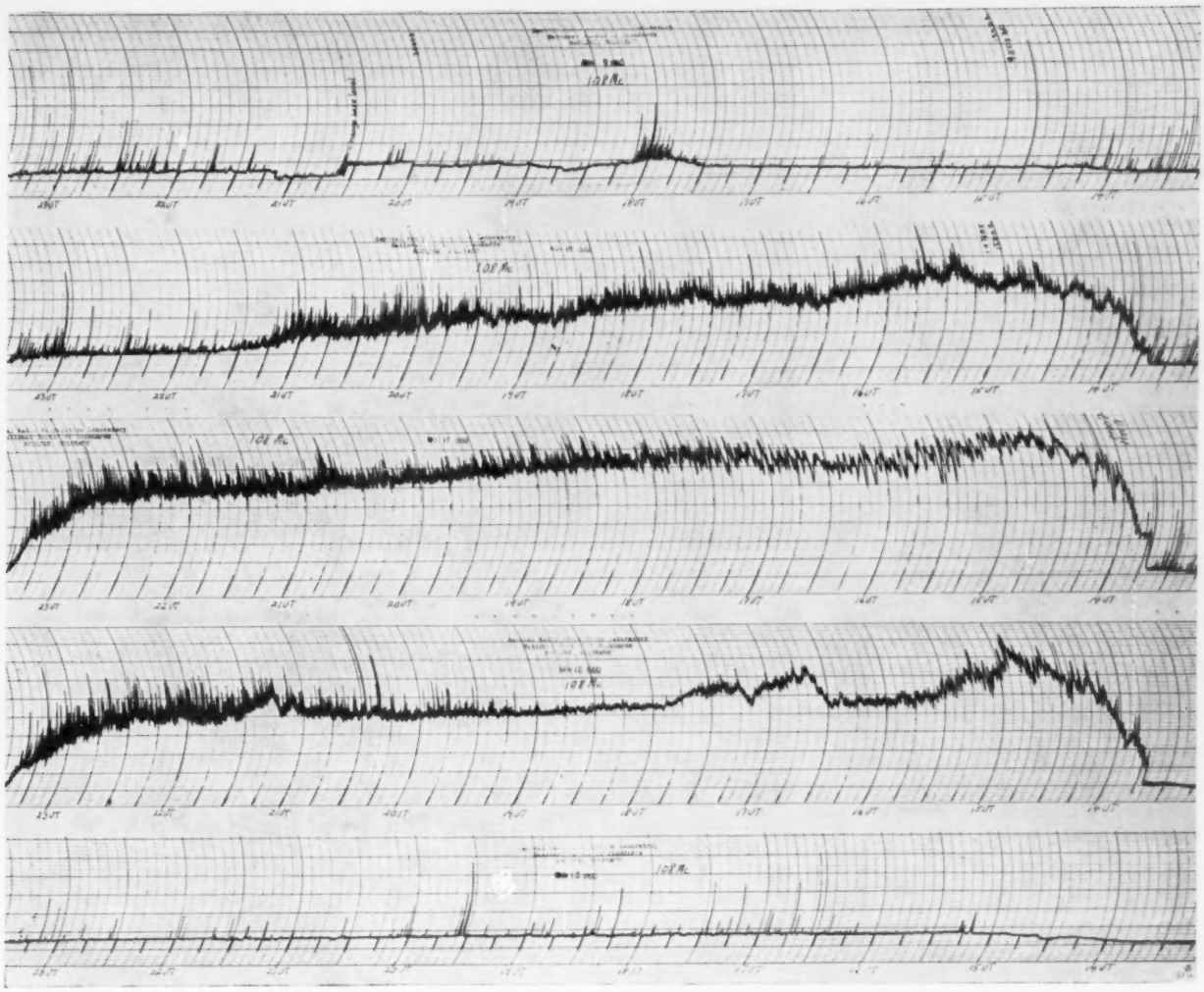
The Fort Belvoir Radio Warning Center operates 24 hours a day, receiving and sending hundreds of messages over four major teletype systems, including that of the World Meteorological Organization. These interconnect virtually all of the commercial communication facilities over the entire world — government, military, and civilian. The duty forecaster is called upon to predict the quality of radio reception and, at times, the best frequencies for transoceanic messages.

His goal is to select a wave length short enough to pass through the lower layers of the ionosphere, yet long enough to be reflected by the upper layers. During a solar storm, the lower regions become dense with absorbing electrons, and a shorter wave must be used. But the upper part of the ionosphere will have become distorted by changes in the earth's magnetic field, and a longer wave will be needed to achieve reflection. If the storm is bad enough, these two limiting wave lengths overlap and short-wave radio communication becomes impossible.

It was on this basis that Weldon predicted the blackout of short-wave communication that prevailed for six hours on the morning of November 13th, just a day after the great flare had appeared on the sun. For almost two days, beginning a little after noon on the 12th, violent reactions were felt throughout most of the usable electromagnetic spectrum. Electric power companies in New York and Canada experienced random and uncontrollable voltage fluctuations



Depending on its wave length, a beam of radio energy sent directly overhead by an ionospheric sounder will be reflected by, absorbed in, or will pass through a layer of the ionosphere. Very high frequencies are relatively unimpeded in reaching outer space. A reflecting layer's height is given by the time lag between the transmitted and returned signal. The density of a lower, absorbing layer is determined from the drop in intensity of a given frequency. Short-wave signals used in long-distance communication are usually reflected by the F region.



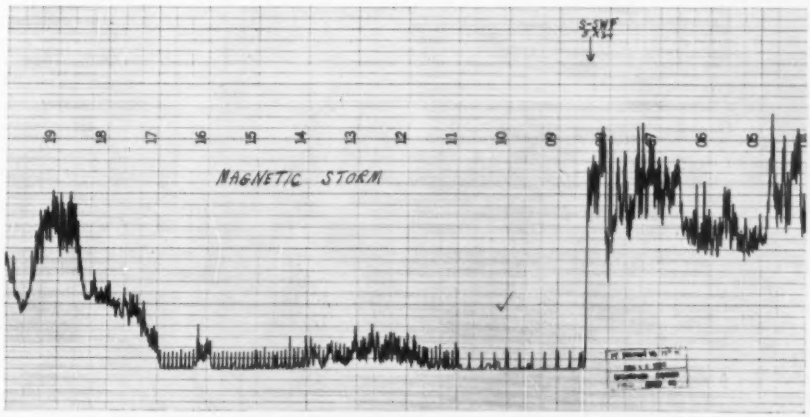
The sun's radio emission at 108 megacycles per second recorded at Boulder, Colorado. From the top, successive strips are daily recordings for November 9-13, 1960, with time increasing toward the left. The noise was unusually intense for three of the five days. Reduced levels at the ends of the curves are due to sunrise and sunset effects.

of considerable magnitude on their transmission lines.

The storm of November 12th was the second in a series of five solar punches that disrupted the earth's atmosphere and magnetic field for almost 10 days. The effects of this kind of activity usually last only one or two days, but with five outbursts in rapid succession the terrestrial disturbances overlapped, with the greatest solar activity in a decade occurring on the 12th. There was a resurgence on the 14th, even more violence on the 15th, and final death throes on November 20th.

The duty forecaster's second main job is an outgrowth of the International Geophysical Year, during which the NBS station served as a hub of global information to alert scientists to unusual solar activity. At the request of the International Council of Scientific Unions, this station continues to act as the World Warning Agency and as the regional warning center for the Western Hemisphere.

As we have seen, on November 12th Weldon called a Special World Interval to increase drastically the intensiveness of solar observations. For eight days, as flare followed flare, he analyzed the increasing flow of data to update his predictions. Daily he considered whether or not to begin, continue, or end Special World Intervals. He called two and extended both. The result? Success — his radio predictions were verified by events, and his timing of the Special



Fort Belvoir monitors short-wave broadcasts. This record for November 12th shows a sudden fadeout just when the solar flare appeared.

World Intervals proved correct. Finally, the sun subsided and normal communications could be resumed.

In addition to their forecasts of radio disturbance for commercial and governmental purposes, the Radio Warning Services furnish ionospheric and geomagnetic measurements for use at the times of satellite launchings. They also distribute announcements of satellite firings, the orbital elements of American and Russian satellites as prepared by computing centers in this country, and disseminate satellite observations made in the Western Hemisphere and overseas. Fort Belvoir and the National Aeronautics and Space Administration have a direct teletype contact. Thus NASA can receive immediate predictions of the best frequencies to use for such programs as Project Mercury, where constant communication between space and ground is essential.

Greater refinement in measurement and prediction is urgently needed. NBS scientists feel that they cannot reliably predict the beginning of a radio disturbance to within better than a 24-hour period. The military users have asked that forecasts of the beginning and end of a disturbance be accurate to within one hour!

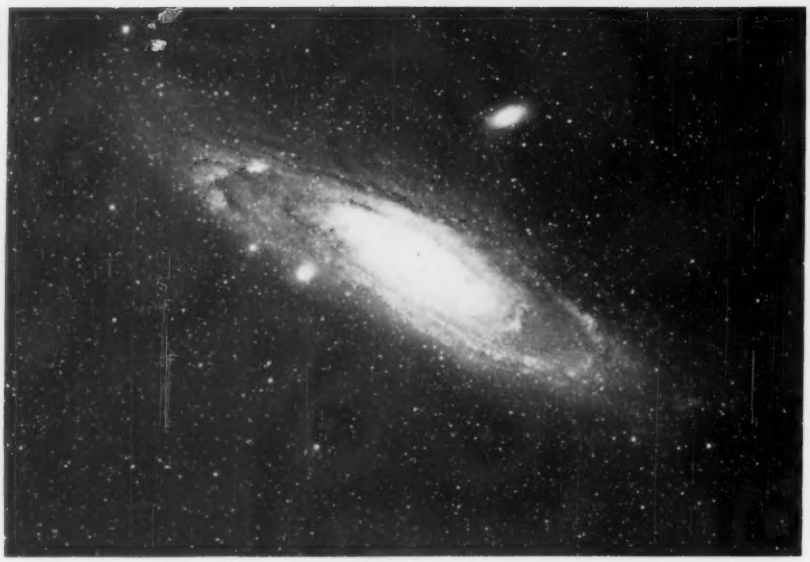
And, as activity declines during the present phase of the 11-year sunspot cycle, the radio predictions are increasingly essential, since the distinction in electron density between the lower and upper ionospheric regions is becoming less sharply defined. This considerably narrows the band of usable frequencies that will pass through to the upper layers and be reflected properly.

Under such conditions, therefore, it is more difficult to find usable frequencies. For this reason, the National Bureau of Standards is spending a great deal of effort to develop new methods of "solar minimum" forecasting. Attempts are also being made to increase the precision of the forecasts geographically — to predict the performance over specific paths instead of merely general areas.

RAPIDLY VARYING STAR

A pulsating variable star with the exceptionally short period of 96.7 minutes has been discovered in the constellation Microscopium by a South African astronomer, J. Churms. During photoelectric measurements of this object, he noticed such rapid changes in the readings that he at first thought the sky was streaked by unseen thin clouds.

Subsequent observations showed that the star is actually a cluster-type variable, with visual magnitude limits 9.28 and 9.60. Only two other variables of this type are known that have still shorter periods: SX Phoenicis, 79.1 minutes, and CY Aquarii, 87.9 minutes. Churms' star is HD 199757, at right ascension $20^h\ 57^m.3$, declination $-42°\ 51'$ (1950 co-ordinates).



The great Andromeda galaxy, M31, is a neighboring Milky Way two million light-years distant. In August, 1885, the supernova S Andromedae appeared in the central region (here overexposed), only 16 seconds of arc southwest of the nucleus. By the following February the star had faded below magnitude 16, and has never been seen since. This 60-minute exposure with a Schmidt telescope has north at the right, west above, a mirror image of the view in an astronomical refractor. Harvard Observatory photograph.

The Elusive Maximum of S Andromedae

SERGEI GAPOSCHKIN, *Harvard College Observatory*

IT HAPPENS in astronomy, as in every science, that a well-established fact remains misunderstood for a long time. This occurred in connection with the famous supernova S Andromedae, which in August, 1885, became visible near the nucleus of the great Andromeda galaxy, Messier 31. That supernova was the first and brightest ever recorded in another galaxy.

Astronomers have accepted and repeated a misleading statement by K. Lundmark in 1920 that S Andromedae was discovered by "Hartwig and others." But there were no "others"; overwhelming evidence points to the German astronomer Ernst Hartwig as the sole *discoverer*, in the strict sense of the word.

A comprehensive review of all the early observations of the supernova was written by Hartwig himself.* Though published in the same year, 1920, as Hartwig's summary, Lundmark's paper was quite independent. The young Swedish astronomer had to depend on numerous scattered accounts that appeared immediately after Hartwig's 1885 announcement of "a highly remarkable change in the great Andromeda nebula." Lundmark knew that half a dozen people, after reading that announcement, recollected they had seen the supernova, but he probably had little interest in analyzing their statements.

There exists some confusion, too, about the actual date of the supernova's maximum brightness. One compiler says merely, "Maximum occurred in August, 1885" — a long interval, indeed; another says that peak brightness very probably fell on August 16th — an impossibility, as we shall see. Careful examination of the facts will clear away many of the difficulties and give the true light curve of the supernova.

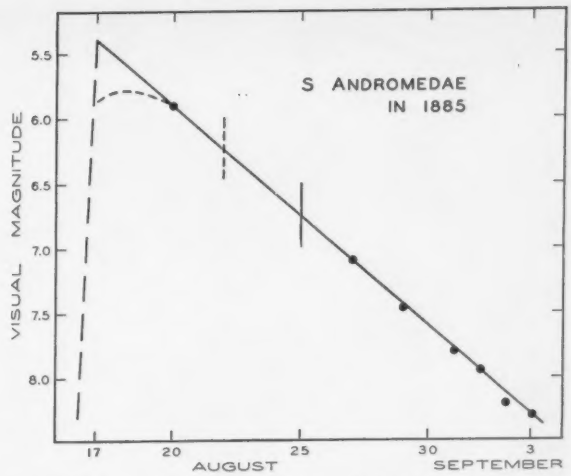
One important reason for all these misunderstandings is that in 1885 astronomers knew nothing about supernovae or about the true nature of spiral nebulae. Also, full moon occurred on August 25th, so the earliest observations of the star were made in bright moonlight, and it was difficult to decide just what kind of change had really taken place in the nebula. Hence several undecided observers did not make any announcement until later.

At the time, Hartwig was a staff member of Dorpat Observatory in Russia. On the evening of August 20th he had been discussing the Laplace nebular theory of the origin of the planets with friends, including a professor of philosophy. He in-

**Geschichte und Literatur des Lichtwechsels . . .* edited by G. Müller and E. Hartwig, Leipzig, 1920, Vol. 2, pages 417-420.

EARLY OBSERVATIONS OF S ANDROMEDAE

1885	*Observation*	*Observer*	*Adopted Mag.*
Aug. 7	no star	Hartwig	—
Aug. 10	no star	Hartwig	—
Aug. 11	no star	Hartwig	—
Aug. 16	no star	Wolf	fainter than 8.0
Aug. 17	"a star in the position of the nucleus"	Gully	5-6
Aug. 20	6.0 or brighter	Hartwig	5.9
Aug. 22 or 23	star	Baroness Podmaniczky	—
Aug. 25	star	Wolf	6.5-7
Aug. 27	7.0	Hartwig	7.1
Aug. 29	7.3-7.5	Hartwig	7.45
Aug. 31	7.5-7.8	Hartwig	7.8
Sept. 1	7.8	Hartwig	7.95
Sept. 2	8.1	Hartwig	8.2
Sept. 3	8.2	Hartwig	8.3



The author here has listed and plotted estimates of the 1885 supernova's apparent magnitude around the time of greatest brilliance. Two interpretations of the peak are possible — sharp (solid line) or rounded (broken curve). Vertical lines show the estimated uncertainty of two indefinite reports.

vited his guests to look at the Andromeda nebula through the observatory's 9-inch refractor, and at once they saw the 6th-magnitude supernova, a "central sun," as if in confirmation of Laplace's theory!

Hartwig immediately realized that an unusual event had occurred in M31. But the director of Dorpat Observatory refused him permission to telegraph to the astronomical news center in Kiel, Germany, until August 31st, when it was possible to confirm the discovery in a moonless sky. Moreover, letters Hartwig had written to Kiel about the details of his observations never arrived, because a mailbox pilferer had stolen the stamps and destroyed the envelopes.

Independently, the supernova was seen in Hungary by Baroness Podmaniczky and a scientific friend on August 22nd or 23rd, but they did not appreciate its significance. It was also noted at Heidelberg, Germany, by Max Wolf — then a young man of 22 — on the 25th and 27th, when he and his father tried to adjust a new small telescope at their observatory. He supposed it to be some appearance due to moonlight.

Much the same thing happened to Prof. Ludovic Gully in Rouen, France, who at a public night at the newly opened observatory turned the coude telescope to the Andromeda nebula and found the supernova already there — on August 17th, three days before Hartwig's discovery! But Gully, instead of attributing it to the moon, believed it due to a defect of the new instrument, which he described as not very satisfactory. Gully's impression of the brightness of the supernova is in full accord with Hartwig's estimate.

Each of these observations was made, it should be noted, not by one person alone, but by a group of people. In every instance there were witnesses, and there was a reason for turning the telescope to the nebula. The circumstances of seeing or not seeing the supernova were given without ambiguity, leaving little doubt of the veracity of the statements. There is also a psychological uniformity to these reports; the Baroness, Wolf, Hartwig, and Gully made no claim to have been the first to see the new star.

Quite different from this is a short statement by the Irish amateur Isaac Ward, published in the *Astronomical Register* for October, 1885. He begins, "The new star . . . would appear from the various accounts to have been first noticed by me on the 19th of August at 11 p.m., when I estimated it about 9½ magnitude. . . ." Ward does not give any details, or tell why he happened to look at the Andromeda nebula. Also, his magnitude estimate disagrees entirely with Gully's observation on the 17th and Hartwig's on the 20th. I believe that this statement cannot be accepted as a true reference to the supernova.

Strangely, Lundmark did not notice Ward's contradiction with Gully, and we cannot tell if he was aware of the existence of the latter's report. Lundmark accepted Ward's account, but changed the magnitude from 9½ to 11½ without giving a reason. The Soviet astronomer P. Parenago, in an article that appeared in 1949, follows Lundmark in accepting Ward, but it does not seem to me that he actually compared the statements of Ward and Gully. If he had, I believe he would have agreed that the Irishman's report did not really refer to the supernova at all.

The way is now cleared for constructing a light curve for S Andromedae near the time of its maximum. The three early-September estimates by Hartwig are confirmed by observations of G. Müller and J. Wilsing, men who were experts in stellar photometry. Hartwig's visual estimations were comparisons with neighboring *Bonner Durchmusterung* stars. It is known that the BD magnitudes need small negative corrections for stars of magnitude 6 or 7, and increasing positive corrections for fainter stars. I have therefore adjusted Hartwig's original magnitudes of the supernova. A straight line through the plotted points indicates that maximum brightness occurred on the evening of August 17th, when Gully showed the nebula to the public. The brilliance of the star would indeed have attracted attention. If, however, the maximum was rounded, the dashed line is a better approximation.

Our results, as indicated by the graph and the table, are the following:

1. At its maximum, the supernova S Andromedae may have been as bright as magnitude 5.4.

2. Maximum took place on August 17th, or possibly, if the light curve was rounded, on the 18th.

3. Hartwig was the only discoverer who recognized from the first that a new star had appeared in the Andromeda nebula.

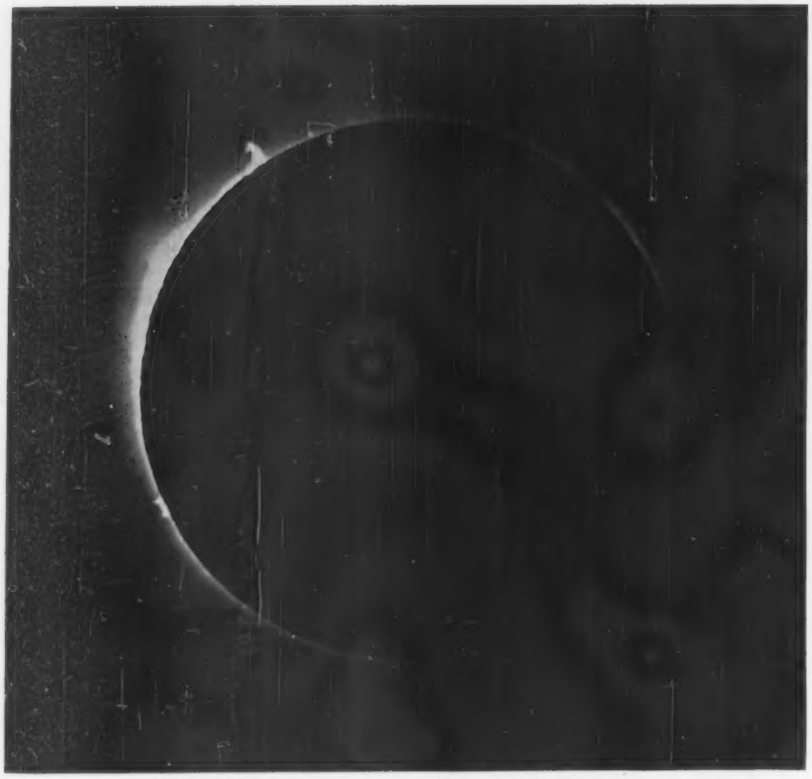
A NEW RADIO TELESCOPE AT GREEN BANK

(Continued from page 311)

miles per hour. In its stowed position, the telescope will withstand 65-mile-per-hour gales.

The steel construction work, scheduled for completion this year, is being done by Bristol Steel and Iron Works, Bristol, Virginia; it will cost about $400,000. Other firms are laying the foundations, building the control house, and putting in an access road. The latter will not pass just south of the reflector, and is shown incorrectly in the cover drawing.

Informal ground-breaking ceremonies took place April 27th, with Dr. Otto Struve, NRAO director, wielding the spade. The observatory's deputy director, Dr. John W. Findlay, is in charge of the 300-foot telescope's planning and construction.



At Arcetri Observatory, Italy, astronomers photographed prominences and some of the inner corona. No eclipse pictures have come from the U. S. S. R.

Soviet Solar Eclipse Observations

DONALD H. MENZEL, *Harvard College Observatory*

AT THE TIME I completed my report on the total solar eclipse of February 15, 1961, for the May issue, I had had no information about observations in the region east of Romania. More than half of the entire track of totality lay within the U. S. S. R., and some reports have now come from various Russian expeditions.

Unfortunately, clouds were generally prevalent over a large part of the path, but here and there clear skies permitted full ground programs to be carried out. As partial insurance against this expected unfavorable weather, the Russian scientists about noon on eclipse day launched a series of rockets from an undisclosed base in the zone of totality.

These rockets carried instrument packages which, on separation from their launching vehicles, became stabilized in their spatial orientation. The Russians believe this is the first time that the solar corona and upper-atmosphere phenomena have been studied during an eclipse from such high-altitude stabilized platforms.

One of these rocket experiments consisted of measuring the corona's ultraviolet radiation in the Lyman region just short of 1300 angstroms, by means of special thermoluminescent phosphors. The Russians also used photon counters for the X-ray regions from 2 to 10 angstroms and 40 to 100 angstroms (the extreme ultraviolet).

They studied the brightness of ultraviolet radiation scattered and reflected inside the moon's shadow, recording photomultiplier-tube readings in the region from 2000 to 3000 angstroms. The field of view was two degrees, and observations showed that the brightness of the scattered radiation was very sensitive to direction.

An infrared radiometer scanned the earth over a range of 180 degrees, covering 2,000 kilometers in a sweep, with a period of 25 seconds. The readings of this device and the other photometers and counters were continuously telemetered to the ground by radio.

The automatic stations photographed the corona through various filters and polaroids, the negatives being recovered by parachute. The far-ultraviolet coronal spectrum was investigated spectrographically, and a number of other experiments were carried out from the stabilized platforms.

With a series of meteorological rockets launched prior to, during, and after the eclipse, the Soviet scientists studied the effects of changes in solar radiation on the earth's stratosphere. The rockets launched during the eclipse reached their assigned altitudes within a few seconds of the intended time. An official announcement reported that the elaborate program had been entirely successful and would solve important scientific problems.

The director of the Central Aerological Observatory stated that meteorologists had sent radiosonde balloons to heights between 20 and 30 kilometers, at several points from Simferopol in the Crimea to Sverdlovsk in Siberia.

V. V. Sharonov observed from a TU-104 jet airplane. Flying 10 kilometers high from Tiflis toward Rostov-on-Don, he encountered the lunar shadow not far from the town of Yeisk, on the Sea of Azov. Professor Sharonov's telescope was so placed in the plane that he saw the corona during all of totality, from first appearance of the diamond ring. The clear dark sky made the corona brighter and even more spectacular than it appeared to observers on the ground. Much photographic material was obtained.

At the Crimean Astrophysical Observatory, astronomers were disheartened when eclipse day brought heavy clouds. But meteorologists carried out a special experiment in the emergency — they flew above the clouds and seeded them with silver iodide. The particles of this crystal have a structure very similar to that of minute ice crystals. Water droplets in a cloud may be supercooled but fail to freeze because no particles are present to condense upon. In such a case, the silver iodide provides nuclei upon which the droplets condense and freeze — the cloud turns into snow, which falls and leaves a clear area in the sky.

This happened in the Crimea on February 15th. By the time of totality the observation area had been cleared. The operation would have been even more successful, according to the French astronomer R. Michard, who was there, had not the relatively high wind kept driving new clouds into the gap and causing the clear area to drift.

Although the sky was not clear enough for the most precise observations, astronomers under the direction of A. B. Severny recorded the ultraviolet spectrum of the chromosphere and took photographs of the corona in selected regions of the spectrum. There were eight solar telescopes, including the large tower instrument, equipped with automatic spectrographs, various wide-angle cameras, and photoelectric devices.

The Crimean Observatory also has extensive radio astronomy equipment, which its staff used to record solar radio noise on different wave lengths as the eclipse progressed. They made additional special studies of the ionosphere and of terrestrial magnetism. At Rostov-on-Don, radio astronomers from Pulkovo Observa-

The central line of the path of totality across the U. S. S. R. for the solar eclipse of February 15, 1961.

tory operated a specially built antenna, and detected a bright source of solar radio noise. Observations at wave lengths of 50 centimeters and 1.5 meters were made near Burakan by scientists from the radiophysics and electronics institute of the Armenian Academy of Sciences.

At Yalta, in the Crimea, a joint Russian and Chinese astronomical expedition put an artificial "radio moon" on the roof of one of the tallest buildings. This beacon furnished a source of radio energy of known intensity, for comparison with the dark side of the moon during the eclipse.

In Bashkiria, S. K. Vsekhsvyatsky led an expedition from Kiev University that obtained successful records of the corona and chromosphere, despite a slight overcast.

Cloudy skies prevailed at Stalingrad, Gorki, Astrakhan, and Ryazan. However, at Saratov the weather began to clear for the eclipse after many days of overcast, and the local population could see maximum eclipse, with 0.999 of the sun's diameter covered, through a slight haze. Because of the expected clouds, many programs were conducted from airplanes.

RADIO ASTRONOMY ROUNDUP

Five of the six feature articles in the April issue of *Physics Today* are devoted to a survey of new developments in radio astronomy. B. F. Burke reports on advances in other countries, F. D. Drake on planetary emission and on Project Ozma, and H. C. Ko on galactic radio noise. K. H. Moore's contribution is a summary of the Colgate University symposium at which the papers were given.

OBSERVING THE SATELLITES

Manned Spaceflight

EVER since Icarus, son of Daedalus, mythically flew too near the sun, mankind has been fascinated by the idea of spaceflight, and bemused by its many perils. Long ages of dreaming, a generation of planning, and a decade of intensive work are now culminating in the achievement of flights into space by vehicles that carry an environment in which man can survive.

At present, the human passengers serve mainly as living proofs of the effectiveness of engineering arrangements for their safety. Already, Yuri, son of Alexei, Gagarin has won fame for surviving his journey around the world, and as this is being written, preparations are being made for an American astronaut's first ride downrange in a Mercury capsule.

Remarkably few concrete facts exist in the torrent of words so far issued concerning the Soviet achievement. There are unresolved discrepancies, and many important details are undisclosed. But from the available Soviet press and radio announcements, the following summary can be drawn.

On April 12, 1961, at 6:07 Universal time, a multistage rocket was launched bearing a satellite spaceship named Vostok (East), with the 27-year-old test pilot, Major Gagarin, aboard. Two-way radio contact was established with him, and he reported as each stage burned out in turn. Through a porthole (according to some accounts) he observed the earth and sky even before attaining orbit. The spaceship's radio transmitters operated on 9.019, 20.006, and 143.625 megacycles per second, a set of frequencies intended to permit contact over a wide range of distances. Also carried were automatic telemetry and two television transmitters, showing Gagarin in profile and full-face. These indicated that "he withstood the period of powered flight satisfactorily."

The pilot was clothed in a spacesuit, for protection in case the cabin lost its pressure. He reclined in a stepped position on a contour seat, in order best to sustain the force of powered flight. The seat was ejectable from the cabin during descent, according to one version.

The cosmonaut's cabin was designed to protect him from accelerative forces, and to insulate him from the heat of passage through the atmosphere, as well as from temperature extremes on the day and night sides of the earth. It kept him pressurized, bathed in air whose oxygen, carbon dioxide, and water vapor content was controlled, protected him from radiation and meteorites, and provided him with a sense of orientation during orbital flight when normal gravitational stimuli were absent. Vostok's cabin was described as more spacious than that of a jet aircraft.

All the features of Gagarin's flight through space could be simulated in laboratories on earth, except for prolonged weightlessness. (Only brief intervals of weightlessness had been obtained, in planes flying parabolic paths.) Reportedly, Gagarin could co-ordinate and control his muscles, and "work efficiently." He monitored operation of the ship's equipment and maintained radiotelephone communication with Earth. (To illustrate one of the complications: Pressing a key would do no good unless the arm was somehow anchored; squeezing the key would operate it.) He observed through the porthole and through an "optical orientator," reporting his observations by radio and recording them in a flight book and on tape.

Gagarin told that he could see coast lines, large rivers, mountains, forests, clouds, and cloud shadows on the ground. He could discern the spherical shape of the earth, and saw its blue halo of atmosphere shading off into a deep black in which the sun and stars shone brilliantly. As he emerged from the earth's shadow (over the South Atlantic Ocean), the horizon appeared bright orange, and a prismatic refraction was observed.

Vostok was approaching the southern apex of its orbit when the Soviet radio broke the news of the first manned spaceflight. Preliminary orbital elements announced at that time were in close agreement with refined calculations published many days afterward. The later values placed the apogee and perigee heights at 203 and 112 miles, respectively, and the inclination at 64°.95. The manned vehicle, 1961μ1, had an orbital period of about 89.33 minutes. Total weight of the spaceship in orbit was given as 4,725 kilograms (10,417 pounds).

Serious discrepancies occur among the

This photograph of Maj. Yuri Gagarin, the first man to survive orbital flight, was provided by the Soviet Embassy in Washington, D. C.

various accounts of Vostok's progress. For example, one dispatch says that Gagarin reported himself over South America at 6:22 UT, while another says 6:52. Actually, it is most unlikely that Gagarin ever passed over South America at all! From given facts of launching, we can infer that at 6:22 the satellite was most probably approaching its northern apex, at about latitude 65° north, longitude 123° east over Siberia, while at 6:52 it had passed over the Aleutians, then west of Hawaii, and was somewhat west of Pitcairn Island. Its path skirted well south of Cape Horn, reaching the southern apex in longitude 69° west at 7:07, and then came northward over the South Atlantic, far to the east of South America. It passed the equator in longitude 15° west at about 7:29. Thus at 7:15 UT, when some reports placed the ship over Africa, it was still far away.

This reconstruction is made possible by numerical data for the path of the launching rocket, 1961μ2, issued by the National Aeronautics and Space Administration from Space Track's reports. The initial period (89.37 minutes), inclination (65°.07), and perigee and apogee heights indicate that Vostok was quite close to its rocket during the first revolution. The discrepancies in the Russian accounts of the orbit of the spaceship probably result from inaccurate reporting (stemming from much secrecy), and do not themselves lend support to speculations that the flight did not take place.

The description of Gagarin's return from orbit is the least satisfactory feature of available reports. In one version, a sun sensor was used to orient the vehicle. In another, the cosmonaut was trained to control his vehicle manually by reaction jets, in response to the position of the earth in a viewing port, or in response to sophisticated instruments, according to a third story. It is generally agreed that the ship was brought down after retro-rockets were fired, but whether the pilot played any role in this is not clear. In one version, the retro-rockets fired at 10:25 UT, and the ship landed at 10:55, but the details are too sketchy to make an accurate estimate of the landing point. Available information suggests this was east of Kharkov, and an indeterminate distance to the north. Latest reports, still unofficial, state the re-entry was automatically controlled throughout.

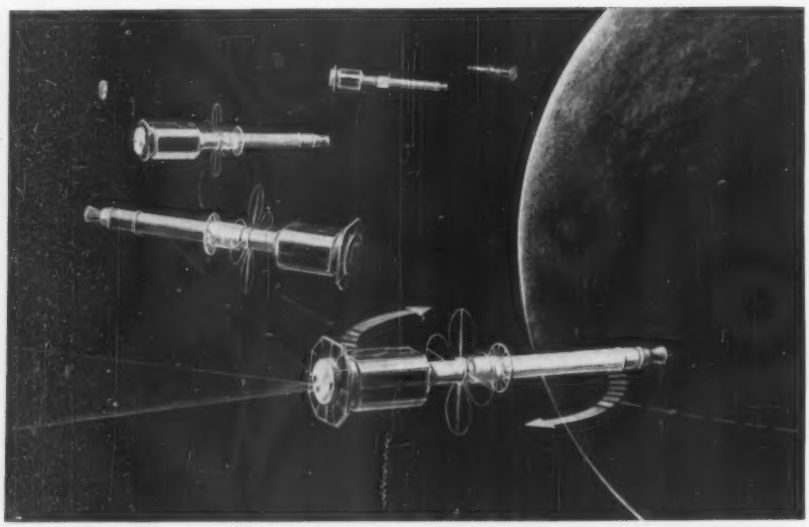
This is the first Soviet launching for which the time of firing was made public. From this fact, and the orbital elements for 1961μ2, it is possible to locate the launching site, though with some uncertainty since the firing program is unknown. One calculation places the launch pad in the vicinity of the Aral Sea, which supports an often repeated guess that the Soviet missile range extends northeastward from the region of Tyura Tam.

Discoverer XXIII

WHEN Discoverer XXIII was launched on April 8, 1961, at 19:21:08 Universal time, from Vandenberg Air Force Base in California, it became Space Track object number 100 (1961λ1). Earlier, on March 30th, Discoverer XXII had failed to achieve orbit. In neither of these military ascents has the nature of the payload been announced.

For some two days Discoverer XXIII is said to have telemetered data from its orbit, but a subsequent attempt to recover its capsule was not successful. Obviously, the orientation was wrong when the retro-rocket fired, since two additional objects with longer periods were later announced as 1961λ2 and λ3.

The Agena stage had an initial nodal period of 94.1 minutes, and was traveling in a plane inclined 82.31 degrees to the earth's equator. Perigee and apogee heights were 184 and 403 miles. Later, on April 24th, the two parts of the recovery capsule — λ2 and λ3 — were moving in orbits inclined 81.94 degrees and having periods of 101.5 and 101.1 minutes, respectively, showing that the retro-rocket increased their velocities when it fired. Perigees for both were about 137 miles and apogees were about 913 and 896 miles.



Immediately after launching, Explorer XI began to spin around its long axis. The satellite's tumbling motion, sketched here, was needed for its telescope to scan both Earth and sky. To add inertia around a transverse axis, the fourth stage was left attached. A hollow doughnut containing liquid mercury was mounted above the rocket's nozzle to dissipate rotational energy. The small aluminum disk shown leaving the payload is a meteoric bombardment shield, removable by ground command. The 88-inch-long package weighs 95 pounds. National Aeronautics and Space Administration picture.

A Satellite for Gamma-Ray Astronomy

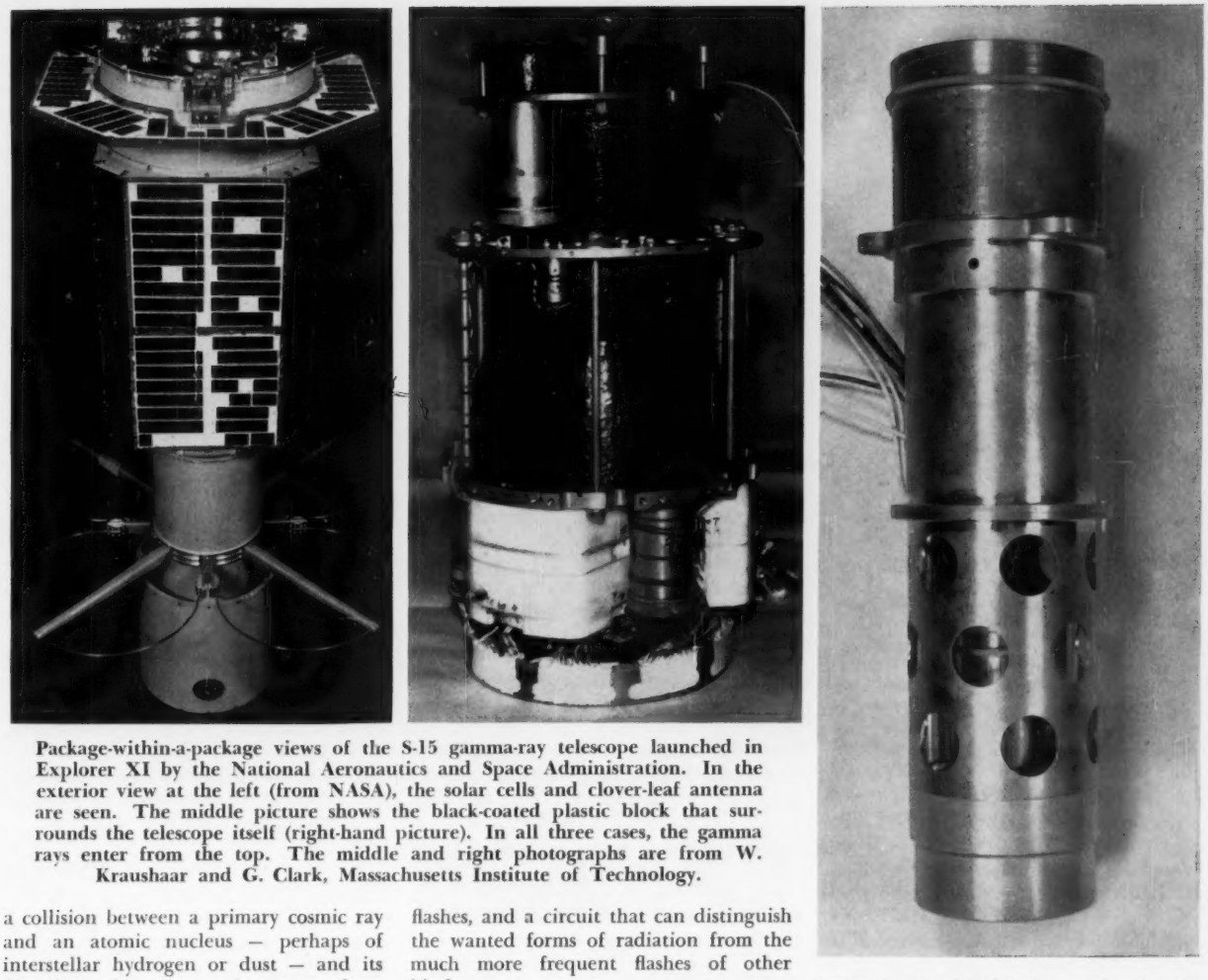
TO LOOK at cosmic radiation within our galaxy in a new way is the main purpose of the gamma-ray-astronomy satellite Explorer XI, sponsored by the National Aeronautics and Space Administration. It was successfully launched from Cape Canaveral on April 27th at 14:16:38 Universal time.

The origin of primary cosmic radiation is one of the underlying riddles of the universe. As yet, too little is known about these very fast-moving protons to decide whether they come chiefly from nuclear processes in supernovae, are accelerated as in a giant synchrotron by galactic magnetic fields, or are being continuously generated throughout the galaxy by conversion of energy into matter. An effective study of primary cosmic rays should provide valuable insight into cosmogony.

Even from artificial satellites that travel well above the earth's dense atmosphere, the primary cosmic rays of galactic origin are hard to measure. Fast-moving protons trapped within the Van Allen belts interfere with observations. Also, since these primaries are charged particles, the direction from which they seem to approach the earth may bear little relation to the region where they originated, as their paths are warped by the magnetic fields of the galaxy, solar system, and the earth itself. However, the true direction of origin can be found for gamma rays, which are high-energy electromagnetic waves.

Those gamma rays that reach the earth's vicinity are thought to provide an indirect measure of the primary cosmic radiation. When fast protons encounter matter, some collisions wreck atomic nuclei, and pi-mesons are born from these catastrophes. Those pi-mesons that are positively or negatively charged decay into products having no role in this experiment. But an electrically neutral pi-meson, after a mean lifetime of less than 10^{-15} second, decays into a pair of gamma rays traveling in opposite directions.

Thus each observed gamma ray signals



Package-within-a-package views of the S-15 gamma-ray telescope launched in Explorer XI by the National Aeronautics and Space Administration. In the exterior view at the left (from NASA), the solar cells and clover-leaf antenna are seen. The middle picture shows the black-coated plastic block that surrounds the telescope itself (right-hand picture). In all three cases, the gamma rays enter from the top. The middle and right photographs are from W. Kraushaar and G. Clark, Massachusetts Institute of Technology.

a collision between a primary cosmic ray and an atomic nucleus — perhaps of interstellar hydrogen or dust — and its direction of motion points away from where this occurred. The intensity of gamma radiation is therefore proportional to the product of primary cosmic ray flux and the density of matter, integrated along the line of sight.

The high energy of the gamma rays indicates that their wave lengths are very short. A neutral pi-meson's mass corresponds to about 135 million electron volts, and to this must be added the considerable kinetic energy the particle had before it decayed. Hence, in a typical case, each of the two quanta of gamma radiation has 100 million volts or more of energy, corresponding to a wave-length band lying below 1.3×10^{-12} centimeter (0.00013 angstrom). The payload of Explorer XI is designed to make a map of the sky at these wave lengths. While the crude chart will require several months of observing, it will be the first ever obtained.

The gamma-ray "telescope" carried in this satellite was kindly described to the writer by William Kraushaar, who designed it with George Clark, another Massachusetts Institute of Technology scientist. The heart of the device is a number of solid masses that scintillate when penetrated by radiation, together with eight photomultipliers to detect these flashes, and a circuit that can distinguish the wanted forms of radiation from the much more frequent flashes of other kinds.

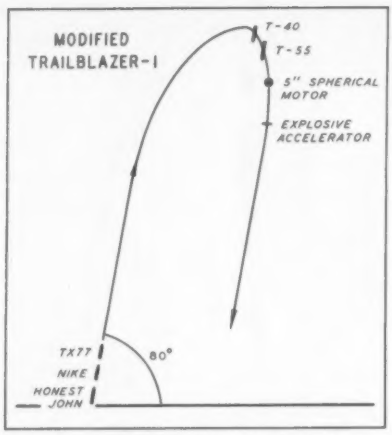
Stacked on one another are five polished crystalline plates, three of cesium iodide alternating with two of sodium iodide, each about 0.2 inch thick and three inches in diameter. Underneath is a photomultiplier to detect flashes in this pile. Any incoming gamma ray that impinges on a nucleus produces a pair of electrons, one positive and one negative, which leave bright trails in the stack. If the ray enters at an angle of less than 12 degrees with the axis of the instrument, the two electrons encounter a lucite block several inches behind the crystal layers, where they induce bright trails viewed by a pair of photomultipliers. Both of the latter must be activated within 10^{-7} second of one another, and while the first photomultiplier is still illuminated by the flash, for the instrument to have any further interest in the event.

When this does occur, a further test must be met — nonillumination of all of five additional photomultipliers. These are arranged to see flashes originating in a plastic shield surrounding the top and sides of the telescope. Two of the detectors are at the upper end of this shield, three below. A trapped cosmic ray from the Van Allen belts would cause scintillation in the shield before activating the inner assembly, and these flashes are carried by internal reflection in the plastic to one or more photomultipliers. (Some are seen in the middle picture.)

The instrument must also discriminate against neutrons, which can imitate the expected behavior of gamma rays, but give rise to short "prongs" of radiation within the iodide crystals. These paths are so short that in the great majority of cases they lie in a single crystal plate, not in two. The duration of scintillations is some five times longer in the cesium salt than in the sodium one. Thus, if the event satisfies other criteria, the manner in which the light intensity inside the stack changes with time will allow gamma rays to be distinguished from neutrons.

In addition to the selective counting of gamma rays, the instrument can be commanded to provide photomultiplier counts from either end of the plastic shield, from the lucite block, or from the crystal stack, either alone or in coincidence with the block. This gives a wide variety of performance data for analysis.

The photomultipliers must be protected from exposure to external light, which would happen if a meteoric particle punctured the black coat of the plastic



The path of the modified Trailblazer rocket assembly is roughly sketched here. No complex guidance controls were needed for this lightweight re-entry research vehicle. The four upper components were stacked nose down in reverse order, with the T-40 at the top when the vehicle was launched. Spin stabilized, the rocket as a whole maintained its initial orientation as it passed the top of its trajectory. Thus, when the T-40 and later stages fired, they accelerated the remaining components downward, parallel to the original upward path.

shield. Hence the latter is covered by an aluminum plate, 0.05 inch thick. But cosmic rays striking the aluminum will generate gamma radiation. To estimate the importance of this effect, the cover is arranged so that it can be blasted away shortly before the end of the experiment.

The gamma-ray telescope is carried in the upper end of the 82-pound satellite, inside an octagonal aluminum box, two feet long and one foot wide. Four surfaces of the box are covered with solar cells. The electronic equipment, tape recorder, and nickel-cadmium storage cells are mounted within an instrument column, 20½ inches long and six inches in diameter. Remaining attached to the assembly is the burnt-out fourth stage of the Juno II launching rocket, weighing 12.8 pounds. This satellite was built and the Juno II launched by personnel of NASA's Marshall Space Flight Center.

Data stored in Explorer XI's tape recorder will be telemetered to earth on command in a selected two-minute period during each orbital revolution. Alternatively, the satellite may be commanded to transmit data as it is gathered without using the recorder. Transmissions are made at a power of 125 milliwatts on a frequency of 107.97 megacycles per second, using a four-leaf loop antenna. The rocket case and the payload, insulated from one another, provide the two halves of the 108.06-megacycle tracking beacon antenna, operating at some 25 milliwatts. It is also used for receiving command signals, which can be sent from any one of four Minitrack stations, at Antofagasta, Chile; Lima, Peru; Quito, Ecuador; and Fort Myers, Florida.

According to NASA's Goddard Space Flight Center, the initial anomalistic period for 1961ν amounted to 108.05 minutes, orbital inclination was 28.80 degrees, and perigee and apogee heights were 302 and 1,111 miles, respectively.

As the gamma-ray telescope scans the heavens, the orientation of the satellite has to be known at all times. Hence two photocells, operated with different sensitivities, serve as earth detectors. The natural tumble of the satellite is expected to provide adequate scanning for the mapping.

Artificial Meteor Experiment

A SEVEN-STAGE ROCKET, believed to be the first ever launched, rose from Wallops Station, Virginia, to a height of 175 miles on April 21st. Coming back toward the earth and accelerating downward, it ejected into the atmosphere a small steel pellet that became an artificial meteor with a speed of some 25,000 miles per hour.

The vehicle was a modification of the 7,700-pound, 56-foot Trailblazer-I, a six-stage solid-fuel rocket that has been used for two years in re-entry research. It is launched from a boom inclined 80 degrees to the horizontal, aiming out over the Atlantic Ocean from Wallops Station. The first three stages, providing the upward thrust, are an Honest John booster, a Nike, and a TX77, the last with slightly canted fins to impart a stabilizing rotation. Peak altitude is reached after about five minutes of flight.

As the Trailblazer began to descend, the next three stages fired, a T-40, a T-55, and a 5-inch-diameter spherical rocket. These directed the rocket downward along a path roughly parallel to the ascent. This permitted the re-entry phenomena to be conveniently observed by radar and optical installations near Wallops Station.

Finally, the steel pellet was fired from a gun-type accelerator. As it plunged into the denser layers of air, the artificial meteor was decelerated and heated by atmospheric resistance just as if it were a real extraterrestrial body encountering the earth.

The experiment was conducted by the National Aeronautics and Space Administration, Lincoln Laboratory, the Air Force Cambridge Research Laboratory, and Harvard Observatory. Astronomers from the last institution made optical observations as part of their general program of research on meteoric phenomena.

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Research Station for Satellite Observation
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QUESTIONS... FROM THE S+T MAILBAG

Q. Why are most published astronomical photographs taken with telescopes other than the 200-inch Palomar reflector?

A. This instrument was designed to have great light-gathering power in a small field, and is thus used mostly for photographing small, faint objects that are beyond the reach of other telescopes. Also, much of its observing time is taken up by spectroscopy and photoelectric photometry.

Q. How can I compute the escape velocity of a planet from the solar system?

A. If the orbital velocity of a planet, moving in a circle around the sun, were multiplied by the square root of two, the planet would escape from the solar system along a parabolic path. In its nearly circular orbit, the earth has an average velocity of 18.5 miles per second; multiplying by 1.414 gives about 26 miles per second for the escape velocity.

Q. Which globular cluster was the first one discovered?

A. Messier 22, in Sagittarius, was noted by Hevelius shortly before the year 1665. Prior to the invention of the telescope, the southern globular Omega Centauri had been charted in Bayer's atlas as a star; it was recognized as a cluster first by Halley in 1677.

Q. What are the symbols that appear by some of the stars on the monthly star charts in Sky and Telescope?

A. These symbols are lower-case Greek letters, which are used with the Latin genitive forms of constellation names to designate the stars. For example, Spica is also called Alpha Virginis. The letters were applied to the brighter stars in each constellation by Johannes Bayer in 1603. The symbols are:

α	Alpha	ι	Iota	ρ	Rho
β	Beta	κ	Kappa	σ	Sigma
γ	Gamma	λ	Lambda	τ	Tau
δ	Delta	μ	Mu	υ	Upsilon
ε	Epsilon	ν	Nu	φ	Phi
ζ	Zeta	ξ	Xi	χ	Chi
η	Eta	ο	Omicron	ψ	Psi
θ	Theta	π	Pi	ω	Omega

Q. What are the brightnesses of the two Martian satellites at a mean opposition and a most favorable opposition of Mars?

A. At an average opposition, the inner satellite Phobos is about visual magnitude 11.5, the outer moon Deimos 13.0. At the planet's closest approach to the earth, the values are about 10.7 and 12.2, respectively. However, the Martian moons are much harder to see than stars of the same magnitudes, because of glare from Mars itself.

Q. What is spectral class *P*?

A. This designation was formerly used for the bright-line spectra of gaseous nebulae.

W. E. S.

Amateur Astronomers

THIS MONTH'S PROGRAMS AND CONVENTIONS

Fayette, Mo.: Mid-States region, Astronomical League. Morrison Observatory, Central College, June 16-18.

Los Angeles, Calif.: Astronomical Society of the Pacific. University of Southern California, June 12-14.

New Orleans, La.: Pontchartrain Astronomy Society, 8 p.m., Metairie playground auditorium. June 2, motion pictures, Project Echo and Path of Venus.

Shreveport, La.: Shreveport Junior Astronomical Society, 7:30 p.m., Centenary College science hall. June 17, R. A. McElvogue, Thiokol Chemical Corp., "The Big Push."

Syracuse, N. Y.: Syracuse Astronomical Society, 8 p.m., Steele Hall, Syracuse University. June 1, Dr. Alan Meltzer, Rensselaer Polytechnic Institute, "Interstellar Dust."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. June 3, Dr. Geoffrey Keller, National Science Foundation, "Radio Astronomy in the United States and Russia."

Wenatchee, Wash.: Northwest region, Astronomical League. Wenatchee Valley College, June 17-18.

TAPESPONDENCE

Several notes have been received in response to the letter by Jarl Plottner on page 95 of the February issue, concerning tape-recorded exchanges of astronomical information and experiences.

Jack Eastman, Jr., 747 26th St., Manhattan Beach, Calif., reports that he has been corresponding by tape with Tom Constanten in Las Vegas, Nevada, for about a year. Mr. Eastman's major interest is lunar and planetary photography.

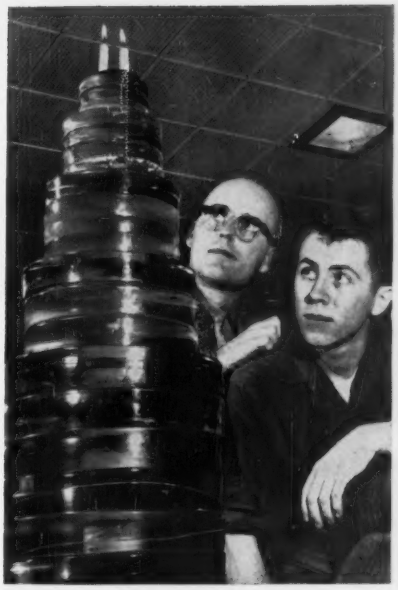
A junior astronomer who wants to arrange exchanges with other juniors is Robert A. Dragon, 65 Rimmon Ave., Springfield 7, Mass.

The Rhode Island Stellar Society's secretary, Dennis A. Wentraub, 36 Greenwood St., Cranston 10, R. I., communicates with the club's out-of-state secretary Philip Dennis in Roselle Park, New Jersey, by letters and tape recordings of parts of the society's meetings. Mr. Wentraub has found that the small plastic reels mailed out by Eastman Kodak with processed 8-mm. movie film are fine for short talks. He only regrets that he cannot save the tapes for reference!

MORE ASTRONOMICAL MNEMONICS

Several readers have submitted sentences whose initial letters indicate the order of the planets from Mercury to Pluto, similar to the one quoted on page 216 of the April issue. L. F. Grandmontagne, Youngstown, Ohio, offers: Man Very Early Made Jars Stand Up Nearly Perpendicular. Alan Izzo, Providence, Rhode Island, gives another version: Mary's Violet Eyes Made John Stay Up Nights Pondering.

Mnemonic sentences or phrases can also be constructed to help recall numbers, each digit being represented by the number of letters in a word. For example, 1.52369, Mars' mean distance from the sun in astronomical units, may be remembered in the form: A fiery or red planet, spherical. Similarly, the equatorial diameter of the earth is "equator difficult to measure" miles.



Dubuque Astronomical Society members "baked" this cake of mirror blanks. Photograph from the Dubuque "Telegraph-Herald."

DUBUQUE, IOWA

Thirty-six members and friends of the Dubuque Astronomical Society recently celebrated its second anniversary with a banquet, followed by astronomical movies and slides taken by club members. Highlighting the dinner scene was a birthday cake made up of 23 partially completed telescope mirrors.

Examining our cake in the accompanying photograph are society president Joseph C. Locher (left) and vice-president Richard Hammerstein.

HOWARD W. KLAUER
1795 Adair St.
Dubuque, Iowa

+++ Amateur Briefs +++

In recognition of his work with the junior mirror makers of the Denver Astronomical Society, Oscar Magnusson received the club's annual presidential award.

F. Addey, director of the solar section of the British Astronomical Association, reminisces that at Portpatrick, Scotland, some 20 years ago, he stood about 250 feet from a 10-foot-high breakwater just as the sun was setting. By stooping, he brought the top of the breakwater upward across the sun, whose altitude was about one degree. At the instant the disk was covered, the green flash appeared, and by repeating the gymnastics Mr. Addey could see the flash a number of times!

Members of the Indiana Astronomical Society are scheduling open houses during the summer, when anyone interested may visit their observing sites. Inquire of Walter Wilkins, 6124 Dewey Ave., Indianapolis 19, Ind., whose phone is FL 7-5946.

Astronomical hobby shows are becoming increasingly popular. Members of the National Capital Astronomers, Washington, D. C., exhibited small telescopes, cameras, eyepieces, drives, photographs, books, and negatives during their April discussion session on telescopes and accessories.

The Dearborn Astronomical Club invites all those attending the Astronomical League convention in Detroit to see its display of telescopes and astronomical equipment. From 10:30 a.m. to 10:30 p.m. on July 1st, the exhibit will be open at the Dearborn Civic Center. On July 3rd the Henry Ford Museum will feature club telescopes, in addition to its vast collection of Americana — decorative and mechanical arts, early architecture, and inventions.

A series of talks on astronomy is being given on the CBC radio program "University of the Air," by the president of the Royal Astronomical Society of Canada, Dr. Peter M. Millman.

On Saturday, June 24th, members of amateur societies in the northeast will meet at Norwell Grange, Norwell, Massachusetts, for informal astronomical talks, a telescope contest, turkey dinner, and a star party. Miss Frances S. Winn, 74 Lincoln Ave., Wollaston 70, Mass., should be contacted for more information and to register for the event, sponsored by the Massachusetts South Shore Astronomical Society.

A highlight of the Astronomical League's Northwest regional convention in Wenatchee, Washington, is to be a public star party in Tedford Park, East Wenatchee, on June 17th. For those visitors too young to reach telescope eyepieces, baby sitters will be provided.

The cover pictures on recent issues of the mimeographed *Astro-Observer* of the Key Biscayne Astronomical Association in Miami have been photographs by group members. Mounted on the April cover is a time exposure of the ill-fated American lunar probe on Thanksgiving morning, 1959, showing the separation of the Atlas-Able rocket's second stage. G. B. C.

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60 to 180 Power

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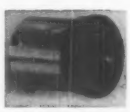

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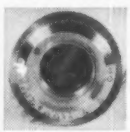

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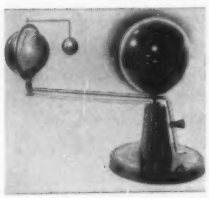

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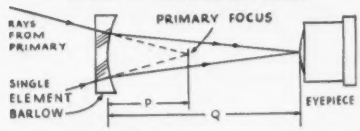

WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to very short-focal-length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q.

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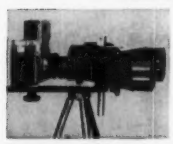

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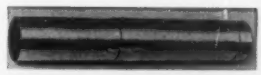

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OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

Identifying the Satellites of Saturn

ALTHOUGH less impressive than the four bright moons of Jupiter, the satellites of Saturn are, perhaps, more challenging to the observer with a moderate-size telescope. The ringed planet comes to opposition on July 19th this year, but it is already well placed for observation, rising about two hours after sunset in mid-June.

Saturn has nine moons in all, but the outermost one, Phoebe, is about magnitude 14.5, beyond the reach of amateurs. The eighth satellite is Iapetus, whose orbit is not shown in the diagram. This 11th-magnitude body requires nearly 80 days to circle the planet, and on June 11th at $11^h.4$ Universal time will be farthest east of Saturn, about nine minutes of arc from its center. Hyperion, which travels the outermost orbit shown here, is of the 14th magnitude, too difficult for most amateur equipment.

The four satellites most readily observed are, counting inward, Titan, Rhea, Dione, and Tethys. The innermost two, Enceladus and Mimas, are not only fainter, but are never far from the planet's glare. This summer, with the rings opened nearly to their full extent, these inner moons are difficult to detect.

To illustrate the use of the diagram, we have selected a time near Titan's eastern elongation on June 9th at $23^h.4$ Universal time, to construct the chart (opposite) showing the observable satellites that evening. The moon will be absent from the sky, so its light will not interfere with observations. Titan will be obvious, looking like an 8th-magnitude star 3′ from Saturn's center and nearly in line with the greatest extent of the rings. Close to this same line, but almost three times as far as Titan from the planet, Iapetus should be identifiable in telescopes that can reach to 12th magnitude.

Rhea's position is obtained by using the intervals from eastern elongation marked along its path. The table tells us that it is at eastern elongation June 2, $14^h.4$, and its synodic period (time of apparent revolution) is 4 days, 12.5 hours. Adding these gives the next elongation on June 7, $2^h.9$, which is 3 days, 3.1 hours before June 10, 6^h, the time of our chart. In the interval, Rhea will move almost three-fourths of the way around its orbit, to a point north of Saturn.

Dione reaches eastern elongation on June 2, $20^h.1$, and has a synodic period of 2 days, 17.7 hours. The successive elongations will occur on June 5, $13^h.8$, and June 8, $7^h.5$. The chart time is 1 day, 22.5 hours later, and Dione will also be north of Saturn, approaching the orbital point labeled 2d 0h. It will be rather near Rhea.

The path of Tethys is not labeled, but its first June eastern elongation occurs on the 2nd at $11^h.9$, while its synodic period is 1 day, 21.3 hours. Successive addition gives another elongation at June 10, $1^h.1$, five hours before chart time. Since the synodic period is 45 hours, Tethys will not have moved far from the east point with reference to Saturn.

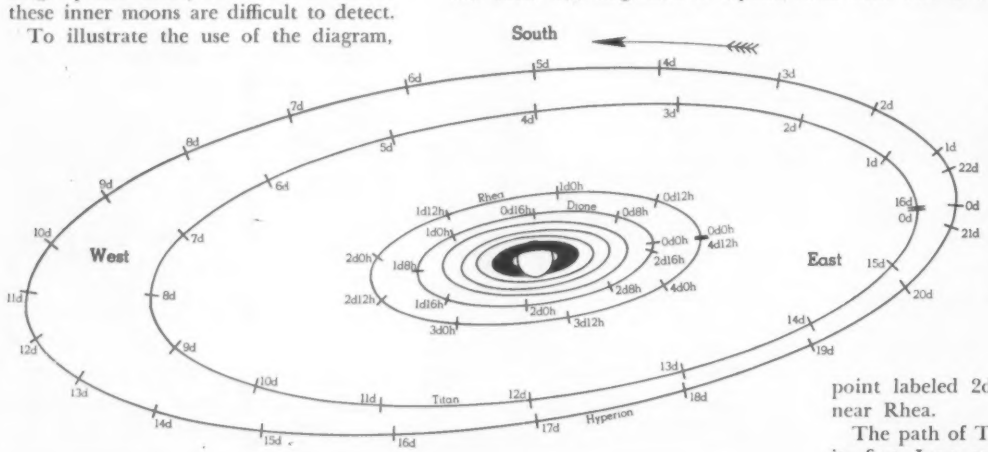
The table gives all the data necessary for similar predictions of orbital positions of Saturn's satellites for any selected epoch this season. Identification of Saturn's moons in a telescope's field of view may be aided by the following remarks concerning some of them:

Iapetus. This satellite undergoes a striking change in brightness, depending on its orbital position. At eastern elongation it is rather faint — not as bright

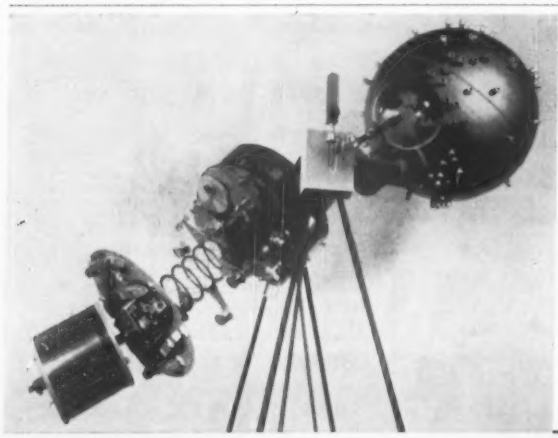
GREATEST EASTERN ELONGATIONS OF SATURN'S MOONS

	Satellite	*Mag.*	*Period*	*Date*	*UT*	*Sep.*
I	Mimas	12.1	$0^d\ 22^h.6$	June 1	$0^h.2$	0′.5
II	Enceladus	11.7	1 8.9	June 2	4.1	0.6
III	Tethys	10.6	1 21.3	June 2	11.9	0.7
IV	Dione	10.7	2 17.7	June 2	20.1	0.9
V	Rhea	10.0	4 12.5	June 2	14.4	1.3
VI	Titan	8.3	15 23.3	June 9	23.4	3.1
VII	Hyperion	14	21 7.6	June 6	21.6	3.3
VIII	Iapetus	var.	79 22.1	June 11	11.4	8.6

This table lists the number and name of the satellite, its magnitude at mean opposition, synodic period, the date and hour (Universal time) of the first eastern elongation in June, and the angular distance of the satellite from Saturn's center at that time. The magnitude of Iapetus varies from 10.1 to 11.9.



This diagram from the "American Ephemeris and Nautical Almanac" gives the orbits of Saturn's satellites for this year's opposition, with south at the top, as seen in an inverting telescope. The arrow shows the direction of motion in the orbits, south being the side nearer the observer.



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The pattern of Saturn's five brightest moons at 6h UT on June 10, 1961 (midnight of the 9th in Central standard time). Far to the east (right) is faint Iapetus, while 8th-magnitude Titan is nearer Saturn. Tethys is also east of the planet, Rhea and Dione north (below). Dot size indicates brightness.

as Enceladus — but at western elongation it is about five times brighter and rivals Rhea. The next western elongation of Iapetus will occur very close to the time of Saturn's opposition in July, so this moon should be watched during June and early July as its brightness increases.

Titan. Of apparent magnitude 8.3, Titan is unmistakable, far outshining its sister satellites. Its actual size about equals Mercury's, but amateur instruments will not show its true disk. Titan requires a little over two weeks to travel around Saturn, so its change of position from night to night is relatively easy to follow.

Rhea. Closer to Saturn than Titan and only one-fifth as bright, Rhea is nevertheless easy to identify. If it is at an elongation one night, look for it near conjunction with Saturn the next evening, and at the other elongation the following night, since the period of revolution is 4½ days.

Dione and *Tethys.* Each about half as bright as Rhea, these satellites might be confused with faint stars in the field of view, were it not for their rapid orbital motion around Saturn, which can be detected after a few hours of watching.

C. A. F.

SOME UNUSUAL OBSERVATIONS OF SATURN AND THE MOON

While reviewing my observing notes of three or four years back, I noticed some more or less unusual items. The observations reported here were made at Khartoum, Sudan, with a 5-inch refractor, the power in each case being 200.

On June 13, 1957, the planet Saturn was viewed under especially good seeing conditions. To my surprise, the outer ring (Ring A) appeared definitely blue. Much care was taken to verify that this was not false color originating in the optical system. Later, I found supporting evidence from an intercomparison of the Saturn photographs in ultraviolet, violet, yellow, and red light, published in H. Spencer Jones' *Life on Other Worlds.*

In recent years there has been much interest in the dark radial bands found inside certain lunar craters. On September 8, 1957, at 18:45 Universal time, only 10 hours before full moon, I was observing the crater Copernicus. Unexpectedly I noticed that the white interior wall was covered by a radial pattern of at least 16 dark bands, two or three of these being lines of dots. The floor appeared dark and the central mountains white. I have not seen any published reference to bands in Copernicus.

While observing the moon on December 23, 1958, I noted that all the maria had a greenish tint. This was not expected, as only certain of them are known to be colored. The greenish hue was also present in the interior of the crater Schickard that evening.

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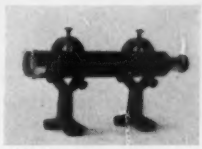

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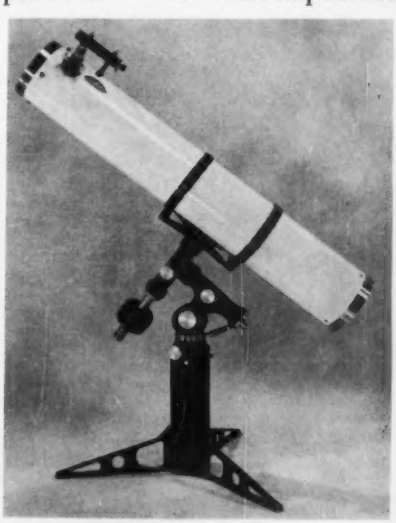

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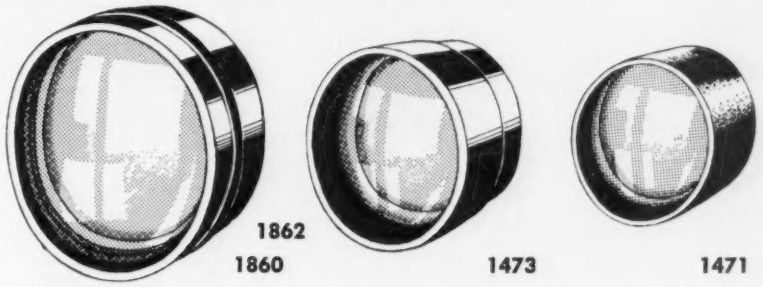

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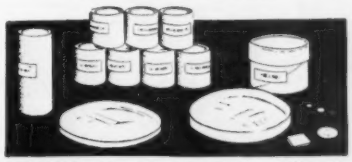

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Messier Objects for Summer Viewing

CONTINUED below is the listing of Messier objects season by season, as drawn up by the Messier Club at the Ottawa Centre of the Royal Astronomical Society of Canada. The tabulation for spring constellations was printed in this magazine for April, 1961, page 219.

During summer months, especially fine Messier objects in each category are available for inspection. All those mentioned below can be well seen in a 3-inch refractor. In Lyra glows the Ring nebula (M57), an oval planetary. Although it shows up rather faintly compared to the needle-point star images in its field, the nebula is quite bright, as may be demonstrated easily by changing the focus of the eyepiece. The out-of-focus star images spread and fade rapidly, but the brightness of the planetary scarcely diminishes.

Globular clusters are plentiful in summer skies, for we can look toward the central parts of the galaxy. The famous Hercules cluster M13 is a particularly rich swarm of stars; at its enormous distance some 400,000 suns would be needed to produce an object having the same brightness.

Among the fine open clusters in this list is bright M11 in Scutum, a fairly large, easily resolved stellar group. Three diffuse nebulae in Sagittarius — the Lagoon (M8), Trifid (M20), and Omega or Horseshoe (M17) — may be readily identified in amateur instruments. And the great Andromeda galaxy (M31) is a perennial showpiece.

M	*Type*	*R. A.* h m	*Dec.* ° ′	*Mag.*	*Size* ′
HERCULES					
13	G	16 40	+36 33	6	23
92	G	17 16	+43 12	6	12
LYRA					
57	P	18 52	+32 58	9	1 × 1
56	G	19 15	+30 05	8	5
CYGNUS					
29	C	20 22	+38 22	7	7
39	C	21 30	+48 13	6	32
VULPECULA					
27	P	19 58	+22 35	8	8 × 4
SAGITTA					
71	G	19 52	+18 39	9	6
SERPENS (west part)					
5	G	15 16	+ 2 16	6	20
OPHIUCHUS					
12	G	16 45	− 1 52	7	12
10	G	16 55	− 4 02	7	12
14	G	17 35	− 3 13	8	7
107	G	16 30	−12 57	9	8
9	G	17 16	−18 28	7	6
19	G	17 00	−26 11	7	5
62	G	16 58	−30 03	7	6
SCUTUM					
11	C	18 48	− 6 20	6	12
26	C	18 43	− 9 27	8	9
SERPENS (east part)					
16	C	18 16	−13 48	7	8
SCORPIUS					
80	G	16 14	−22 52	7	5
4	G	16 21	−26 24	6	23
6	C	17 37	−32 11	6	26
7	C	17 51	−34 48	5	50
SAGITTARIUS					
17	D	18 18	−16 12		46 × 37
18	C	18 17	−17 09	7	7
23	C	17 54	−19 01	7	27
24	C	18 16	−18 26	6	4
25	C	18 29	−19 17		35
20	D	18 00	−23 02		29 × 27
21	C	18 02	−22 30	7	12
8	D	18 01	−24 23		90 × 40
28	G	18 22	−24 54	8	15
22	G	18 33	−23 58	6	17
69	G	18 28	−32 23	8	4
70	G	18 40	−32 21	9	4
54	G	18 52	−30 32	8	6
55	G	19 37	−31 03	5	15
75	G	20 03	−22 04	8	5

Symbols for type of object are: C, open cluster; D, diffuse nebula; G, globular cluster; P, planetary nebula. 1950 coordinates and approximate visual magnitudes are given.

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DEEP-SKY WONDERS

THE TWO most dazzling globular clusters in all the heavens are Omega Centauri and 47 Tucanae. The latter is in declination −72°, and hence never rises for places north of Jamaica or Guatemala. Omega Centauri, however, is in theory visible from latitudes up to +43°. I have repeatedly seen it on the meridian while observing at Manhattan, Kansas, and this cluster is a relatively easy object for American amateurs in the southern tier of states.

Most of us need a low, unobstructed southern horizon to glimpse Omega. This globular stands highest in the sky when Spica is on the meridian, directly above it. If you live near the northern limit of visibility, try 65-mm. binoculars from a high hilltop on a very clear night. The cluster will appear as a large patch of light, dimmed by atmospheric extinction.

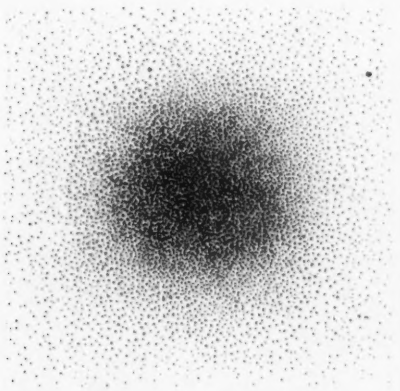
Omega Centauri, marked on some charts as NGC 5139, is located at right ascension $13^h\ 23^m.8$, declination −47° 03′ (1950 co-ordinates). The dense swarm of many thousand stars is about 23′ in diameter, and its full splendor can be seen only from the Southern Hemisphere. Sir John Herschel gives a vivid description of Omega's appearance in his 18-inch reflector in South Africa on March 3, 1837: "All clearly resolved into stars. . . . This most glorious object fills the whole field *with its most condensed part*, and its stragglers extend ¾ of a field beyond it either way. It is very conspicuous to the naked eye as a dim cometic looking star, 4 m or 5 m."

Observers in southern California or Arizona and New Mexico might also look for the 9th-magnitude spiral galaxy NGC 4945, which would be well known were it in northern declinations. It is a long spindle, 11½′ by 2′. Some years ago, at Eagle Pass, Texas, I recorded it as "surprisingly bright." The position is $13^h\ 02^m.4$, −49° 01′.

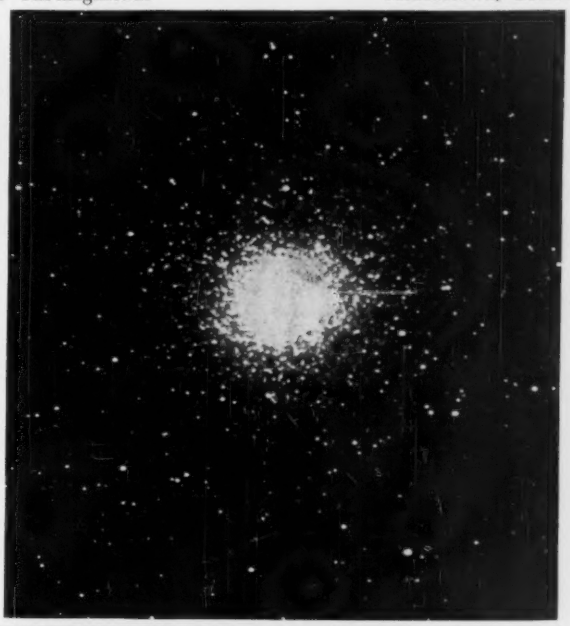
A more accessible globular, well worth the hunting, is M68 (NGC 4590) in Hydra. At $12^h\ 36^m.8$, −26° 29′, it lies just under the "sail" of Corvus. This 8th-magnitude cluster is easily found in a rather sparse star field. Admiral Smyth long ago claimed a mottled aspect, which I have never been able to confirm.

An hour east of M68 and three degrees south is the big broadside spiral M83 (NGC 5236), about midway between Gamma Hydrae and Theta Centauri. It is at $13^h\ 34^m.3$, −29° 37′. About 10′ by 8′ in angular size, this 9th-magnitude galaxy looms in the eyepiece field. The fact that M68 and M83 were discovered with 18th-century telescopes used at Paris (farther north than Montreal) indicates that both objects can be readily picked up by small amateur telescopes anywhere in the United States.

WALTER SCOTT HOUSTON
36 Lawn Ave.
Middletown, Conn.



John Herschel's drawing made over a century ago shows Omega Centauri as he saw it in an 18-inch metal-mirror reflector at the Cape of Good Hope.



This photograph of the globular cluster Omega Centauri was taken by James E. Gunn at Beeville, Texas, with his 8-inch reflector. It is enlarged five times from a 40-minute exposure on Eastman 103a-F emulsion. Mr. Gunn describes his telescope and guiding arrangements on page 358 of this issue. According to Dr. Helen S. Hogg, this great cluster is 15,000 light-years distant and has a total brightness about equal to a 4th-magnitude star. If the earth were at the center of this cluster, its stars' collective light would equal several thousand full moons, the illumination matching terrestrial twilight.

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FOR SOME TIME I have been using the 18-inch refractor of the University of London Observatory to search for unreported rilles upon the moon's surface. I have found many of them that are not on any published lunar map, although they are easy features in the 18-inch and should be visible in a good 10-inch instrument. Some of my findings were described in SKY AND TELESCOPE, November, 1960, page 286.

The crater Jansen B is just north of the center of Mare Tranquillitatis, on the edge of an old ruined ring. It has a peculiar shape, being elongated to the west, and is similar in appearance to Torricelli and König. In this vicinity is a system of several very delicate rilles, some of which may be traced on G. P. Kuiper's *Photographic Lunar Atlas*.

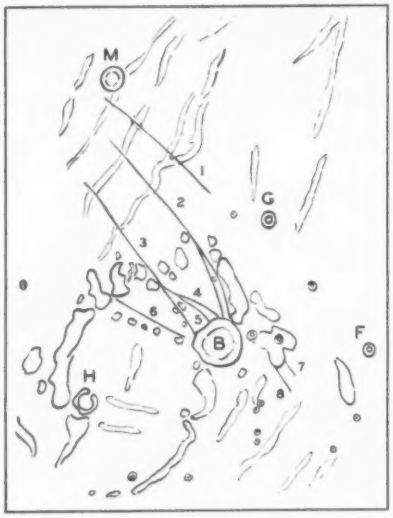
The accompanying chart is based upon Kuiper's atlas, with details added from visual observations on November 8, 1960. It shows numerous parallel wrinkle ridges running from northwest to southeast, which are part of the local lunar grid system. The almost square crater Jansen H has a large gap in the southern part of its wall, the crater sides being parallel to the ridges.

A number of fine rilles run nearly perpendicular to the ridges. Of these, rilles 1 to 6 were observed visually, while 7 and 8 are suspected from an examination of Kuiper's atlas. Rilles 1 and 2 are shown in the atlas, perhaps also 3.

This rille system is important, for ordinarily such features run *parallel* to wrinkle ridges, and rilles crossing ridges are almost unknown. Three of my objects, 1, 2, and 3, cross several ridges, producing gaps in them. This is unexpected; usually a rille meeting an obstacle such as a crater wall either ends or seems to tunnel under it. The present observations imply that the rilles were formed after the wrinkle ridges.

My studies of various parts of Mare Tranquillitatis lead me to believe that in this region there are scores of rilles still to be found.

BRIAN WARNER
2 Diamond Cottages
Crawley Down, Sussex, England



Brian Warner's chart of the Jansen B area shows rilles seen with an 18-inch telescope at 2h Universal time on November 8, 1960. South is upward.

SUNSPOT NUMBERS

The following American sunspot numbers for March have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

March 1, 12; **2**, 22; **3**, 33; **4**, 24; **5**, 28; **6**, 31; **7**, 33; **8**, 41; **9**, 33; **10**, 20; **11**, 17; **12**, 13; **13**, 18; **14**, 44; **15**, 40; **16**, 55; **17**, 52; **18**, 39; **19**, 31; **20**, 33; **21**, 50; **22**, 53; **23**, 60; **24**, 71; **25**, 67; **26**, 70; **27**, 70; **28**, 85; **29**, 90; **30**, 102; **31**, 98. Mean for March, 46.3.

Below are provisional mean relative sunspot numbers for April by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations in Locarno and Arosa.

April 1, 87; **2**, 60; **3**, 55; **4**, 73; **5**, 86; **6**, 82; **7**, 64; **8**, 66; **9**, 49; **10**, 48; **11**, 47; **12**, 42; **13**, 40; **14**, 41; **15**, 53; **16**, 60; **17**, 78; **18**, 72; **19**, 65; **20**, 56; **21**, 52; **22**, 47; **23**, 41; **24**, 36; **25**, 48; **26**, 60; **27**, 82; **28**, 74; **29**, 92; **30**, 99. Mean for April, 61.8.

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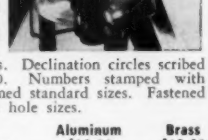

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This photograph of the moon's southeast quadrant, showing the craters Tycho and Clavius, was made by the 3.5-inch Questar telescope, which weighs 7 pounds. It was made on 35-mm. film at sea level. There is remarkable detail, as much as found in pictures taken with much larger instruments. Compare it, for example, with Anton Kutter's fine 12-inch Schiefspiegler photograph on page 67 of the December, 1958, *Sky and Telescope.*

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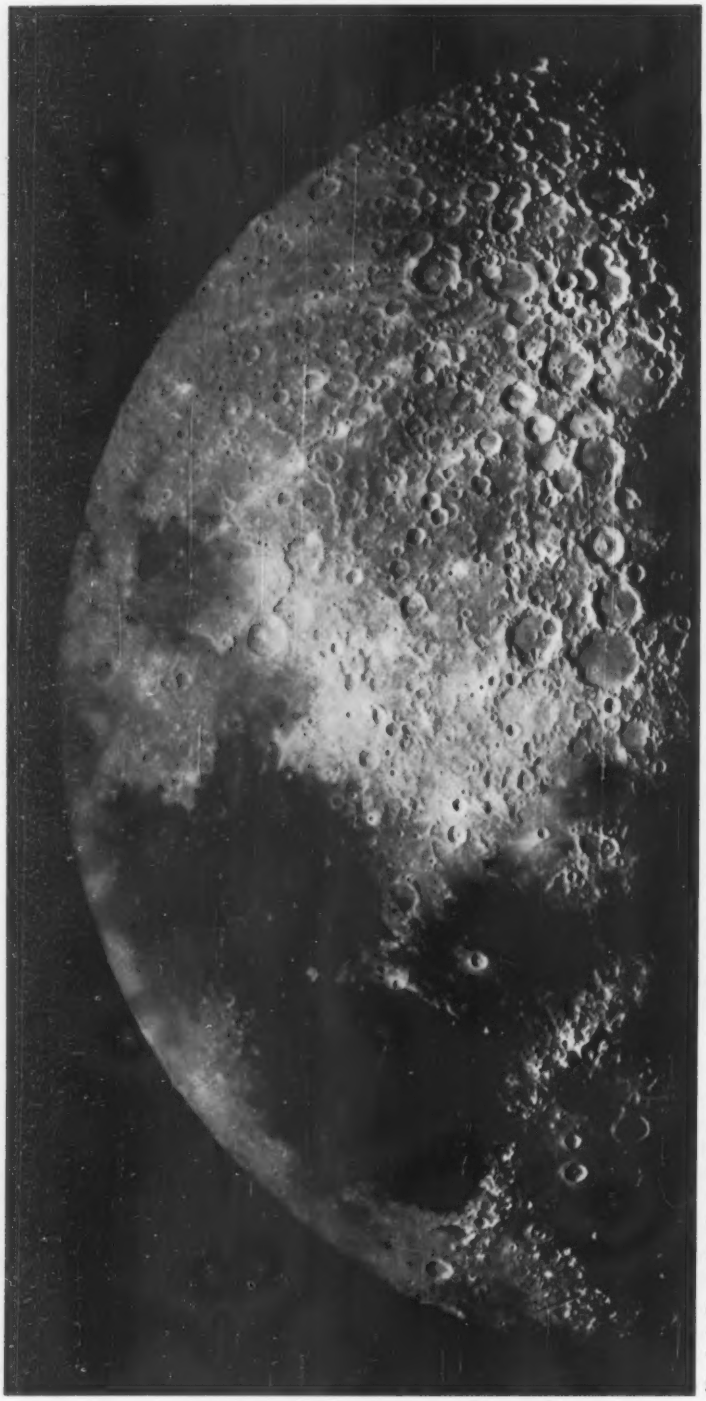

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BOOKS AND THE SKY

COSMIC RADIO WAVES

I. S. Shklovsky. Harvard University Press, Cambridge, Mass., 1960. 444 pages. $12.50.

THIS English translation of a book which first appeared in 1956 has been revised and augmented by the author to provide the reader with most of the important results in radio astronomy research obtained before late 1959. Nevertheless, since its original printing virtually half the modern developments in radio astronomy have occurred, and the first question that should be answered is, "Does this book belong on the research worker's desk, or with the historian of science?"

Were the author a lesser man than I. S. Shklovsky, the latter would probably be true, and this work would be stale today. However, we are dealing with one of the leading thinkers of the astronomical profession, and the ideas of such a man do not depreciate much in only five years. Furthermore, his skill in selecting those observations and theories that were both well-established and significant has given his tract a strong resistance to obsolescence. And, although time has betrayed the author in several important instances, the synchrotron mechanism of radio emission, so vital to all his theories, has not been replaced by any more appealing idea. It is, in fact, even more firmly entrenched than when the book was initially written. Dr. Shklovsky's work *is* alive, to the point, and very useful in 1961.

Cosmic Radio Waves is for the professional; only a brave, well-trained layman would consider its purchase worth while. The book is detailed and mathematical, and theoretical discussions are at the technical level of a graduate physicist. Even descriptions of instrumentation are meant for the physicist, rather than the electrical engineer. Although very well written, the work must be read closely, to keep up with the intricate and careful logic of its author.

The translation is extremely good, and Harvard is to be congratulated on having two well-trained astronomers, R. B. Rodman and C. M. Varsavsky, do this work, for the translated technical words have precisely the right meaning. There is not a single example of such a classic error as translating the Russian for "P Cygni star" as "R Lebedi star."

The review of early radio observations is excellent. There are top-quality discussions of the physics of the synchrotron mechanism and of 21-centimeter-line observations, the possibility of observing other spectral lines at radio frequencies, the Crab nebula, and the theories and observational data concerning the general galactic magnetic field.

The high point of *Cosmic Radio Waves*, where Shklovsky's original thought shows most brilliantly, is the chapter "Radio Astronomy and the Origin of Cosmic Rays." Here he builds a mosaic in which supernovae, nonthermal galactic radio emission, relativistic particle components of the interstellar gas system, terrestrial cosmic rays, and the galactic magnetic field are all interrelated to produce a theory which fits existing data. This has been one of Dr. Shklovsky's main lines of interest, and possibly nobody could have presented it better.

Only two chapters have been severely hurt by the passage of time since the book was first published. One, "Extragalactic Radio Waves," discusses a field in which there has been a great deal of activity in the last few years, rendering obsolete many older observational data and interpretations. It is now known, for instance, that such radio sources as Centaurus A, Fornax A, and perhaps Cygnus A, form an important class in which an apparently single object is accompanied by two greatly extended areas of radio emission lying far from its optical portions.

Also, the importance of intergalactic collisions in explaining cosmic radio emission has greatly decreased, partly through the author's own efforts. We now know that multiple galaxies have a strong tendency to be radio sources, but probably not because they are in collision. The apparent ellipticity of the Virgo A source (M87) has been discovered to be spurious, a result of blending with a nearby source (M84). Many of the extragalactic 21-cm. observations discussed by Dr. Shklovsky have been found to be in error, and few of the conclusions reached from this data are still tenable.

The chapter "Receivers and Antennas in Radio Astronomy" gives only a poor picture of modern instrumentation. The formulas necessary to determine the minimum detectable signal of a radiometer are given, but the final relation (1-10) for this signal is incorrect. The stated formula would give, for a good maser radiometer, a sensitivity about 10 times poorer than the actual value.

The author has also accepted the quite widely held notion that a cosmic source can be detected when it generates a radiometer response as large as the root-mean-square fluctuation in the instrument output. In actual fact, experience and Monte Carlo analyses have shown that the intensity has to be about five times greater for definite source detection, thus increasing the necessary observing time by a factor of 25.

Dr. Shklovsky is noted as one of the great freethinkers and speculators in modern astronomy, and it is interesting to compare his conjectures of 1956 with what is current belief in 1961. His famous as-

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sertion that Cassiopeia A is a supernova remnant has now been universally accepted. He noted that Centaurus A and Fornax A may be alike and hinted that this may be significant, as indeed has turned out to be the case. He predicted that radio emission from flare stars should be observable; the Jodrell Bank telescope has apparently accomplished just this. Dr. Shklovsky conjectured that the galactic nucleus must be a very peculiar region, exerting an influence over large parts of a galaxy; this now seems to be true.

Perhaps he does make one notable mistake on page 88, where, in a refutation of the possibility that stellar objects may be significant radio sources, he states, "By now it has become perfectly clear that investigations in this direction lead to a dead end." Just recently the radio source 3C 48 has been identified with an optical star — or is this object just another one of Dr. Shklovsky's supernova remnants?

On page 340 we find one of his most intriguing thoughts — that the earth has occasionally passed through the shells of supernovae, at which time the cosmic-ray intensity increased perhaps hundreds of times, resulting in major effects on biological evolution.

More time must pass before we can know if this and other unproven ideas are correct.

FRANK D. DRAKE
National Radio Astronomy Observatory

AN INTRODUCTION TO ASTRODYNAMICS

Robert M. L. Baker, Jr., and **Maud W. Makemson.** Academic Press, New York, 1960. 358 pages. $7.50.

WORKERS in the new field of astrodynamics — the engineering application of celestial mechanics, geophysics, propulsion theory, and allied studies to the problems of space vehicles — will welcome this book containing a wide spectrum of information.

The text is divided into two main sections, "Fundamentals and Background" (chapters 1-5) and "More Detailed Analyses" (chapters 6-12). The material in it has been used for a short intensive summer course at the University of California at Los Angeles for a number of years, and can serve, according to its authors, for a junior semester-length or senior full-year course. Prerequisites are sophomore physics, and mathematics through calculus. The reader is assumed to be acquainted with the elements of vector analysis, but no knowledge of classical mechanics or astronomy is presupposed.

In Chapter 1 is given some historical background concerning the classical problems in celestial mechanics, followed by the study of the elements of a two-body orbit, the harmonic law and *vis viva* integral, velocity components, equations of absolute and relative motion, and a prospectus on perturbations. This chapter may be confusing to a beginner who is reading the book on his own. For instance, the section on the elements of a two-body orbit utilizes the equations of motion that are developed three sections later. Terms are used that are not defined immediately (perifocal passage, for example, a term that astronomers may find novel). Some definitions are stated inexactly.

The brief section on perturbations may lead to further confusion. Perturbative forces are defined as "forces acting on an object other than those forces that cause it to move on some *reference* orbit." This description is offset in later chapters, however, by fuller and more adequate explanations. The authors' statement that canonical methods are in general "impractical albeit sophisticated" is certainly open to question.

The next two chapters review briefly but comprehensively the state of our present knowledge of minor planets and comets, and give areas for future investigations. This material is well written, providing a largely nonmathematical and interesting interlude before the plunge into the main business of astrodynamics. Again, a tyro will find some of the compendious information unintelligible, for example, expressions like "secular variation of the obliquity of the ecliptic" and "lunar equation." Some astronomers might wish to quibble about the statement that Bode's law is nowadays considered an "irrational prediction." Bessel's theory for the secular acceleration of Encke's comet is presented, but Whipple's explanation is omitted. Considering the astrodynamical importance of Venus, Mars, and our own moon, one wonders why these bodies were not given at least as much prominence as asteroids and comets.

Most astronomers will agree with the suggestion in Chapter 4, "Geometry and Coordinate Systems," that no attempt be made to justify the "logic" of the astronomical vocabulary. "Just as in the case of a foreign language it must be accepted by merit of its general usage and not revised to suit the taste of the individual." This dictum has been largely ignored by

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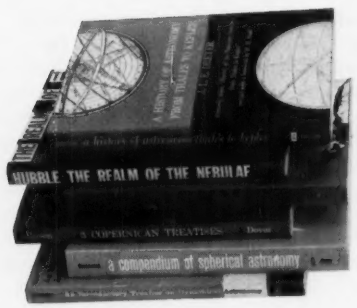

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the new generation of post-Sputnik space scientists, but is being readopted, thanks to closer association with professional astronomers, courses in dynamical astronomy, and books like the present one.

Perhaps the main meat of the work is contained in chapters 6-9, dealing with orbit determination and improvement, the *n*-body problem, special perturbations, and general perturbations. These subjects are treated cursorily, with the intention that graduate students or others reading the text will go on to detailed analyses from the list of references given in the bibliography. Worthy of mention are orbit-determination methods depending on range and range-rate data only. The section on normal places is clearly presented. However, differential correction of orbits, a subject that is of paramount importance in guided trajectory work, is treated in too general a manner. Here Newton's admonition *exempla magis prosunt quam praecepta* (examples are more helpful than rules) would be in order. The emphasis on orbit correction, rather than the redetermination of orbits on the basis of new data, is well placed.

A chapter on nongravitational and relativistic effects contains much useful information and is well written. Special and general relativity are explained in only six pages, but are clearly presented.

Observation theory and its application to interplanetary orbits conclude the volume. We find some condensed results from spherical astronomy and astrometry, and quite a bit of new material on current observing methods, such as the Baker-Nunn camera, image-intensification and infrared techniques, interferometer, Doppler radar, and HIDOP systems. All this useful information is adequately covered. The application to interplanetary orbits is an extension of some of the work of previous chapters. Of particular interest is the consideration of effective gravitational cross section, a concept useful in capture processes, as well as the brief discussion on space navigation and correction techniques.

Following the text is the extensive glossary, without which a reader with no previous knowledge of the subject would be lost. While *apareon* is defined, *periareon* is not. *Topos,* which is used in several places in the text, is not defined.

The enormous bibliography has 175 references, most from current literature, but it is surprising to find few references to standard works on celestial mechanics or orbit determination. The book concludes with 70 well-thought-out problems of varying degrees of complexity, and author and subject indexes. The diagrams and printing are clear and the book's text has a minimum of typographical errors. Where diagrams are far from their references, it would help if page numbers were given.

This reviewer feels that *An Introduc-*

tion to Astrodynamics is on the whole a useful handbook of information in the many fields of space science. Because of the heavy reliance for derivations and subject matter on Samuel Herrick's *Astrodynamics*, which is now in press, it is essential to have the latter work, when it becomes available, as a companion volume for understanding much of the Baker-Makemson text. And it is seriously doubted that the prerequisites stated by the authors are sufficient background for students to tackle the greater part of the material.

MORRIS S. DAVIS
Yale University Observatory

NINE PLANETS

Alan E. Nourse. Harper and Bros., New York, 1960. 295 pages. $5.95.

WHAT do we know about the planets? What problems face the astronaut who would explore them? What kind of life, if any, can we expect to find on neighboring worlds? These are some of the questions the author of *Nine Planets* attempts to answer in "a book calculated to fulfill a need, seeking to plug some of the gaping holes in our thinking about the solar system and to integrate fact and speculation in a slightly unorthodox but fruitful manner."

Such topics as man's motivation for leaving his planet, the members of the solar system likely to receive priority during early space travel, and distances involved are discussed in the first two chapters. Succeeding chapters present the major and minor planets and consider the possibility of solar systems beyond our own. In each case the reader is first introduced to "established facts," which then provide a basis for the author's speculations.

Unfortunately, the factual sections are very uneven in quality, and no more than a casual perusal indicates that the author has not always kept up with the most recent findings. For example, W. M. Sinton's spectroscopic evidence for the existence of organic substances on Mars, and the photometric determination of Pluto's rotation period by M. F. Walker and R. Hardie, seem to have eluded attention. An irritating feature of this book is that the reader is almost never told where information was obtained, nor is he given any indication where he could search further.

For the most part, the speculative sections are more successful, and frequently the author's experience as a physician lends color to his statements. In discussing conditions on Mars, he writes: "Any human being unwise enough to try breathing the Martian atmosphere without protection would scorch the mucous membranes of his nose, throat and lungs just as effectively as if he had inhaled concentrated sulphuric acid." But even in these

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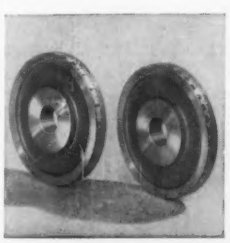

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For a more detailed atlas, the 16 charts developed by Antonin Becvar and his associates at the Skalnate Pleso Observatory in Czechoslovakia are available. 35,000 stars to magnitude 7.75, with double, multiple, and variable stars, novae, clusters, globulars, and planetaries, bright and dark nebulae, galaxies, the Milky Way and constellation boundaries, are printed in many colors in the **De Luxe Atlas of the Heavens**, the 16½" x 23" maps being bound in a heavy cloth cover. *$9.75.*

Observers at their telescopes will find the inexpensive **Field Edition** of the Skalnate Pleso Atlas a most convenient star reference. 16 sheets of stiff paper, 18" x 12¼", are printed in white on a black background, so they may be illuminated with a flashlight without spoiling the viewer's dark adaptation. The charts are unbound, *$4.00* per set; two sets for *$7.50.*

Antonin Becvar's **Atlas Coeli-II, Katalog 1950.0** is the most complete check list of celestial objects ever offered to the amateur observer. Given, with descriptive data, are the 6,362 stars brighter than magnitude 6.26, with their right ascensions and declinations, magnitudes, and much other useful information; extensive lists of star clusters, nebulae, and galaxies. Cloth bound, 367 pages, *$8.75.* The catalogue makes a fine companion to the *De Luxe Atlas of the Heavens,* and they sell together for *$17.50.*

Lunar observing is more informative with **Elger's Map of the Moon**, a large canvas-mounted chart identifying all important lunar features. Notes by H. P. Wilkins on 146 areas are given. The lunar chart itself is approximately 18" in diameter. *$3.00.*

In two colors, and over 10" in diameter, the **Sky and Telescope Lunar Map** identifies most important features on the moon, including 326 mountains, seas, and craters. The map is good for use with groups at star parties: individual copy, *25 cents;* 3 to 100 maps, *20 cents* each; over 100, *10 cents* each plus postage.

The constellations are easily identified from any location in latitudes 52° to 32° north with the aid of **Philips' Planisphere**. This world-famous star finder is printed in dark blue and gold, and can be set quickly for any time of year. Directions for using the device are given in four languages. *$3.00.*

Decorative as well as informative is the **Color Map of the Northern Heavens**, a large wall chart showing the northern sky in polar projection to declination −43°. Such important star groupings as Gould's belt, the Scorpius-Centaurus association, the blue stars of Orion, are all indicated by the star symbols, colored vividly to show spectral class. 30" x 34½", only *$1.00.*

Announcing

AN ATLAS OF THE MOON'S FAR SIDE

The Lunik III Reconnaissance

On October 4, 1959, the Soviet Union successfully launched its third space probe, Lunik III, into orbit around the moon. Carrying a battery of intricate scientific equipment, including photographic and television systems, it passed near the moon, oriented so as to view a portion of the lunar surface that is perpetually hidden from the earth. On command it photographed the moon's far side for 40 minutes, and these images were later telecast to the earth.

The results of this achievement were compiled and edited for the U. S. S. R. Academy of Sciences by three Soviet astronomers, N. N. Barabashov, Kharkov University Observatory, A. A. Mikhailov, Pulkovo Observatory, and Yu. N. Lipsky, Sternberg Astronomical Institute. Dr. Lipsky summarized this work in Sky and Telescope for March, 1961, page 133. Now the complete Russian *Atlas of the Opposite Side of the Moon,* translated into English by Richard B. Rodman of Harvard Observatory, is being published jointly by Interscience Publishers, Inc., and Sky Publishing Corporation.

This English edition contains every fact, every illustration, in the Russian original. It includes an introduction, "The Photographs and Their Transmission," "Interpretive Techniques," "The Photometric Cross Sections," "Reduction of the Material," and replicas of all 20 full-page plates with their 30 halftone pictures of hitherto invisible lunar features. These pictures have been obtained by means of electronic filtration processes from the best original negatives taken by Lunik III. A major part of the book is the detailed catalogue identifying and describing 498 lunar formations. The definitive map is given in two forms — both as four full pages in the book, and as a separate 17" x 24" folding sheet. 200 pages (8⅜" x 11⅞"), 20 plates. **$7.00**

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Amateurs thinking of constructing a 6-inch reflecting telescope are reminded of Allyn J. Thompson's **Making Your Own Telescope.** Complete step-by-step directions for making and mounting the instrument at low cost are given in easy-to-understand chapters. No complicated mathematics is involved, and no prior knowledge of optics is needed. 211 pages, 104 illustrations (7th printing). **$4.00**

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pages one might question the basis for some conclusions. Dr. Nourse envisions Mars as having once been populated by an intelligent race which, faced with a dying planet, has among other alternatives "long since left the solar system and gone to the stars." He uses an almost Lowellian interpretation for the existence of the canals, without objectively presenting evidence against such a viewpoint.

The chapter on the satellites is refreshingly original and more detailed than the coverage in other similar books. Diagrams of satellite distances are useful.

On the whole, *Nine Planets* is sparsely illustrated. There are 12 paintings by Mel Hunter (four in color) which are, according to the author, "scientifically accurate and frankly speculative." The 22 diagrams are all simple and appropriate. Two appendices giving planetary data and a short glossary, together with a fairly detailed index, conclude the book.

The text itself contains many minor factual mistakes. For example, on page 118 Patrick Moore is cited as insisting that "the largest telescope on Earth of any value in giving us information about the planets of the solar system is a 50-inch refractor instrument." On page 161 Schiaparelli "turned the lens of a fine reflecting telescope toward the disc of Mars," and on page 234 Nereid is said to be "a retrograde moon."

Although Dr. Nourse's speculations concerning life and the general conditions to be found on our neighboring planets are interesting, unorthodox, and even provocative, the many shortcomings of the factual information it presents make *Nine Planets* a book which has to be used with reserve and caution.

ERNST E. BOTH
Kellogg Observatory
Buffalo Museum of Science

THE MOON: OUR NEAREST CELESTIAL NEIGHBOUR

Zdenek Kopal. Chapman and Hall Ltd., 37 Essex St., London WC 2, England, 1960. 131 pages. 25s.

SINCE 1946, when the first radar contact with the moon was achieved, a revolution has been under way in lunar studies. The powerful observational tools of radio astronomy and optical astrophysics have been applied at an increasing tempo, and close-up investigations from space vehicles have begun. Physicists and geologists are joining astronomers in developing stimulating new ideas about our natural satellite.

Zdenek Kopal's book is a nontechnical report on this revolution. He is professor of astronomy at the University of Manchester, England, which has been an active center of lunar work. Thus he is in a position to interpret many recent developments, hitherto scattered in research papers.

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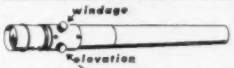

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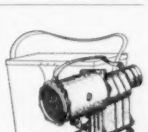

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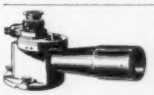

2" objective; Kellner eyepiece; Amici erecting prism; 4 built-in filters; reticle illumination; field is 6° (325 ft. at 1,000 yds.). The focusing 28-mm. eyepiece allows focus from 15 ft. to infinity. Weight, 5 lbs. These were used by the government for antiaircraft. Government cost over $200.00. Price **$12.50**

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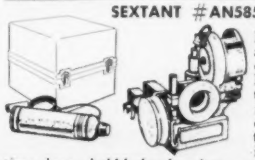

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book is its clear account of radio observations of thermal radiation from the moon, and how they lead to the conclusion that the surface is dust covered. There is a lucid explanation of modern tests for the existence of a lunar atmosphere and a lunar magnetic field, both of which have so far resisted detection.

Readers will find detailed accounts of N. A. Kozyrev's 1958 observation of activity inside the crater Alphonsus, and the Lunik III photographs of the moon's far side. Another story, too little known, is the discovery by J. Dubois and by Kozyrev of a luminescence repeatedly occurring in the Aristarchus region, apparently due to bombardment by solar corpuscular radiation.

The discussion of these topics is well-informed and generally balanced, and the reader profits by the author's firm grasp of the astronomy and physics involved.

Nevertheless, *The Moon* is an uneven book. The introductory portions were hastily written, and their organization is not good. Chapter 7, with its speculations about the moon as a future Utopia, could well have been replaced by more solid fare.

Strictures like these do not apply to the main body of the work. But one curious misstatement on page 30 deserves mention. There the reader is given to believe that all crater walls and mountains have slopes inclined less than 10 degrees to the horizontal. Were this true, no black shadows could be observed on the moon more than 10 degrees from the terminator. The reader of the book has only to turn to Plate IX, a photograph of the Mare Imbrium region, where he will find many small craters containing shadows indicating steeper slopes.

J. A.

NEW BOOKS RECEIVED

ATOMS TO GALAXIES, *James Stokley*, 1961, *Ronald*. 360 pages. $6.00.

The solar system is emphasized in this anecdotal introduction to astronomy by one of the science's well-known popularizers.

MEYERS HANDBUCH UBER DAS WELTALL, *Sebastian von Hoerner* and *Karl Schaifers*, editors, *Bibliographisches Institut*, Postfach 311, Mannheim 1, West Germany. 369 pages. DM 12.60.

Meyer's Handbook of the Universe is a compact encyclopedia of astronomical information. The German text contains numerous tables and diagrams, photographs, a moon map, and eight large removable star charts.

INTRODUCTION TO SPACE AGE ASTRONOMY, *John M. Cavanaugh*, 1960, *Educational Services*, Washington 6, D. C. 166 pages. $2.75, paper bound.

Information on the naming of the zodiacal constellations and the months of the year is included in this very elementary description of astronomy. A workbook section gives crossword puzzles, questions, and cutting-out exercises.

PHYSICS OF THE SOLAR CHROMOSPHERE, *Richard N. Thomas* and *R. Grant Athay*, 1961, *Interscience*. 422 pages. $15.50.

This detailed mathematical monograph combines two parallel investigations of the sun's lower atmosphere. One is a theoretical study of the chromosphere, in which the classical assumptions of local thermodynamic equilibrium and negligible motions are abandoned. The second is an evaluation of the thermodynamic state of the chromosphere from analysis of observations, especially those made at the 1952 solar eclipse expedition.

STRUCTURE OF THE MOON'S SURFACE, *Gilbert Fielder*, 1961, *Pergamon*. 266 pages. $7.50.

A leading British selenographer presents a semitechnical summary of modern findings regarding the moon's surface relief, the lunar atmosphere, bright rays, rilles, ridges, and the lunar grid system. Very extensive chapter bibliographies are given.

SPACE IN YOUR FUTURE, *Leo Schneider*, 1961, *Harcourt, Brace and World*. 260 pages. $3.75.

Planets, stars, nebulae, astronomical tools, and space exploration are introduced to the junior high school student. Many diagrams and illustrative experiments requiring very little equipment supplement the author's explanations.

INTRODUCTION A L'ASTROPHYSIQUE: LES ÉTOILES, *Jean Dufay*, 1961, *Librairie Armand Colin*, 103 Blvd. St.-Michel, Paris 5, France. 218 pages. 4.50 NF, paper bound.

The director of Lyons and Haute Provence observatories summarizes current knowledge of the physical properties of stars from an observational viewpoint in this small French-language book, *Introduction to Astrophysics: The Stars*.

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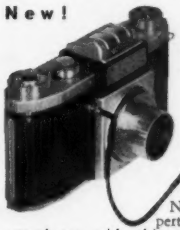

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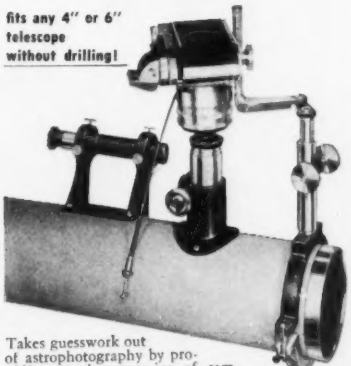

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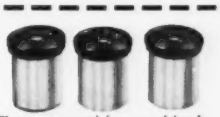

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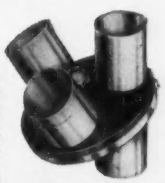

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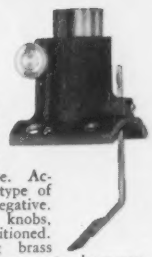

The most mechanically perfect focusing is by rack and pinion. This mount takes standard 1¼″ eyepieces. Full 3½″ of travel — more than ever before. Accommodates almost any type of eyepiece — positive and negative. Two knurled focusing knobs, variably tensioned and positioned. Solid cast-metal sliding brass tube — close tolerance prevents looseness. Mount aligns itself to any type tube. Four mounting holes, nuts and bolts included. Eye mount has square-rod-type diagonal holder which prevents loose alignment and vibration. Rod tempered to minimize temperature changes. Adjustable for 3″ to 8″ scopes, also 12″ scopes if so specified at no extra cost. Order one or more of the complete eyepieces described below at the same time you send for this rack-and-pinion device, which accommodates any of our eyepieces perfectly.

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S-53	1.50″	8½″ to 9½″	**10.00**
S-54	1.75″	9½″ to 10½″	**12.50**
S-55	2.00″	11″ to 11½″	**14.95**
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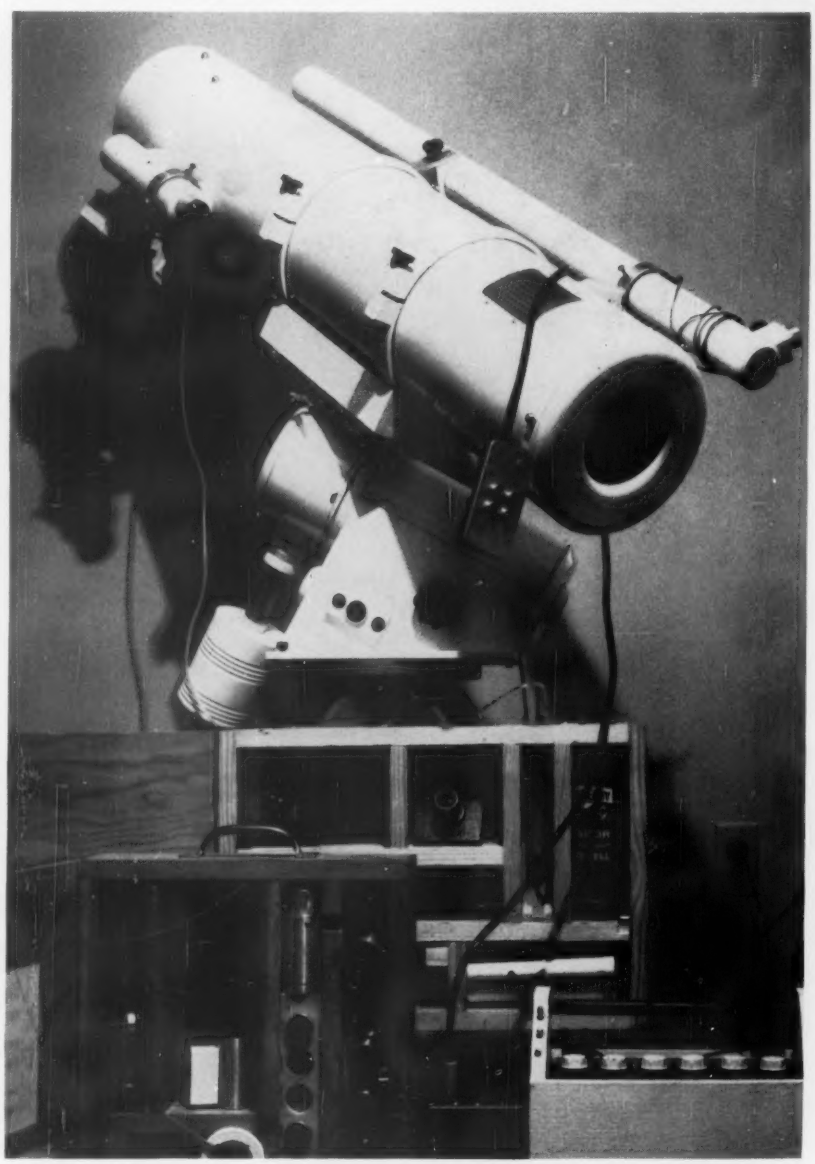
An 8-Inch Reflector with a Transistor-Controlled Drive

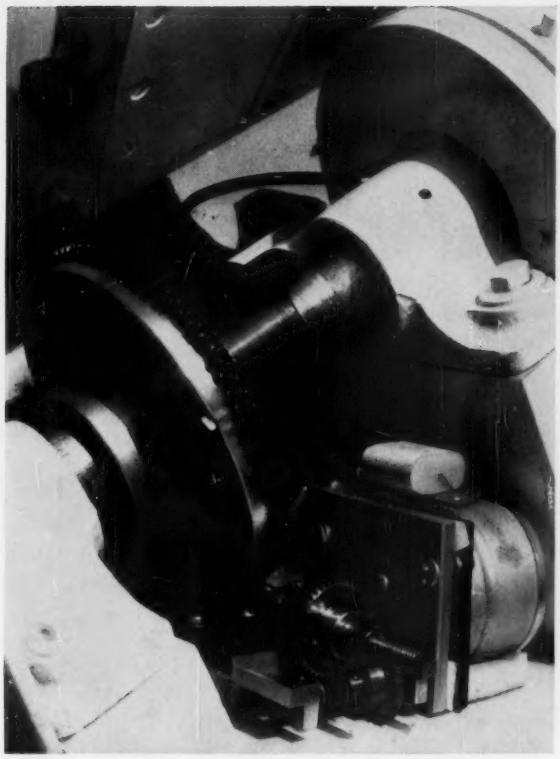
With celestial photography as my major interest, I began to make an 8-inch Newtonian telescope about five years ago. It was recently completed and fully equipped, and I have been able to obtain satisfactory photographs of clusters, nebulae, and bright galaxies. An important feature of the instrument is a transistorized control for the drive in right ascension, permitting accurate guiding during long exposures. In one instance, I obtained a successful 90-minute picture of the Horsehead nebula in Orion.*

The 8-inch mirror is of short focus, 43", the focal ratio of f/5.4 giving bright images and reducing exposure times necessary for faint objects. The conventional German equatorial mounting incorporates porous-bronze polar-axis bearings and

*ED. NOTE: This and other photographs by Mr. Gunn will be published in a forthcoming Sky and Telescope. His picture of Omega Centauri is on page 345 of this issue.



James E. Gunn's 8-inch telescope has a 2¼-inch guide telescope (upper right) and a finder (upper left) near the camera which is partially hidden in the shadow. The knurled knob on the west side of the polar axis housing is the manual slow motion control in right ascension. During observing, the base rests on a ⅜" steel plate secured to an 8" pipe set in concrete. All photographs with this article are by the author.



The clock drive and its gear train. The 7-watt, 10-r.p.m. motor at lower right drives a 16-tooth spur gear (not visible) through vibration-reducing Tygon tubing. The spur engages another gear of 72 teeth which turns a worm (bottom center) for a 40-tooth gear. The latter is on the main worm shaft; in the picture the worm is hidden by the polar axle gear. Pressure of a spider nut on the main worm shaft clamps the 40-tooth gear to the shaft, on which it otherwise turns freely while the manual slow motion is being used. The main driving gear is a standard Boston 80-tooth from which the spokes and hub were cut. The 80-tooth gear is friction mounted with a breakaway clutch, which re-engages immediately whenever the telescope reaches a new observing position.

babbitted declination bearings. Careful balancing provides adequately smooth motions without the use of ball or roller bearings.

Both axes have electric drives controlled from the usual four-button punch block, hanging from the lower part of the telescope tube in the picture (facing). The main tube was rolled from 1/16″ aluminum and is lined with sheet cork for thermal control. Ventilation around the rear of the mirror and through the screens just forward of the mirror surface assists in securing thermal equilibrium while the telescope is being set up and focused. During an exposure the screen ports are closed to prevent dewing of the primary.

The tube may be rotated around its long axis when used visually, but to maintain balance when the heavy guide telescope and the camera are in place, it must be kept fixed. Although allowance has been made for a prime-focus head to be interchanged with the Newtonian one, I have decided that the latter is more practical for this size of instrument.

The guide telescope (upper right in the picture) is an f/20 refractor of 45-inch focal length, equipped with a built-in 3x Barlow. A 15-mm. symmetrical eyepiece with illuminated crosshairs is used for guiding at a power of 200. No higher power would be useful, as the Airy disk is plainly visible at this magnification.

Also seen in that picture is the transistorized oscillator-amplifier, mounted on the side of the battery case in the lower right. In the left foreground is the visual accessory case, containing eyepieces, a Barlow lens, focusing adapter, tools, filters, and the like. In the center is the plate accessory box, which holds the field-viewing assembly (upper left), the Foucault focuser, the guiding-reticle battery and brightness control, the control cylinder for the pneumatic shutter, and a planetary camera (lower right). The largest black disk in the lower left corner of the mounting housing is the eyepiece of a right-angled telescope used in aligning the polar axis by sighting on Polaris.

The declination drive is powered by a small permanent-magnet direct-current motor that rotates a 300-tooth tap-cut worm gear mounted inside the cradle. This in turn drives a 90-tooth gear in the declination housing, which engages the screw of a tangent arm. The mechanism is the simplest and smoothest I have seen.

The polar-axis drive employs the 110-volt synchronous motor and gear mechanism seen in the accompanying close-up picture. A mean solar rate is achieved when 60-cycle current is supplied to the motor, and the amplifier-oscillator provides sidereal and guiding rates. My observing site at Beeville, Texas, at the present time has no 110-volt source, but the transistorized control and a 12-volt car battery provide dependable power.

The control was patterned after George W. Ginn's, described in *Scientific American* for October, 1959, but uses standard transformers instead of special hand-wound ones. The electronic components, mounted in a minibox attached to the battery case, can be easily assembled by the average radio amateur familiar with soldering techniques. The front end is a transistorized Wien-bridge oscillator fur-

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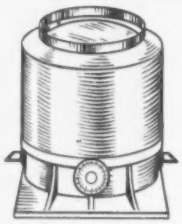

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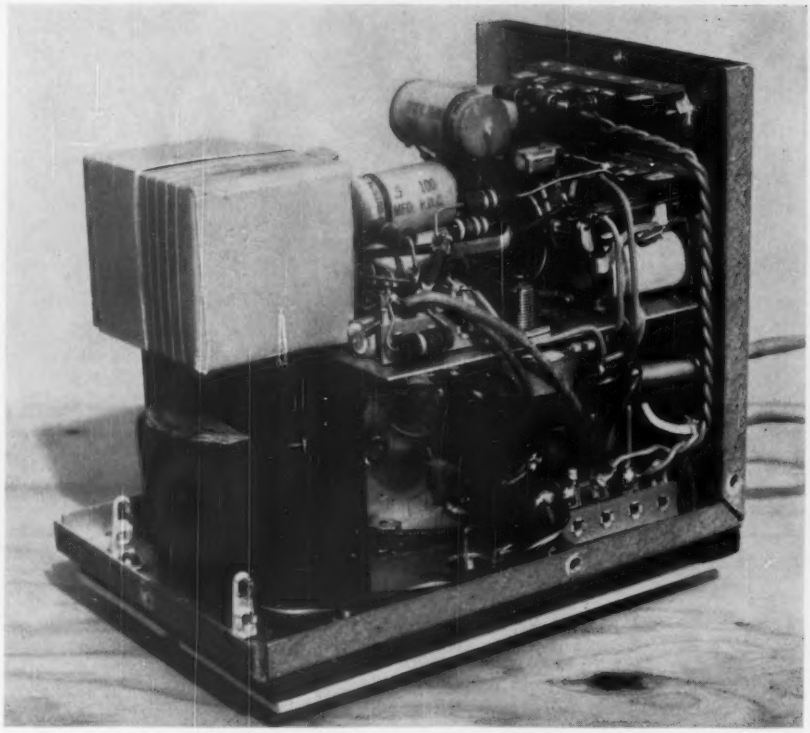

The amplifier-oscillator for the Gunn telescope, unlike much transistorized equipment, was found to work well in cold weather, though it had been adjusted in the summertime.

nishing a frequency variable from about 55 to 65 cycles per second; in operation this oscillator proves to be very stable.

In the photograph, the output transformer may be seen at lower left. The battery just above it is an assist for the war-surplus 24-volt relays, since these do not work reliably on 12 volts. The oscillator is assembled on the upper subchassis, while the power amplifier is below. A ganged fine-speed control is seen in the upper sub-chassis, attached to the front panels. The shaft terminates in a knob for easy trimming.

My amplifier is quite ordinary, using only standard components. A 12-volt supply and a 7-watt Hurst motor have an advantage over Mr. Ginn's unit in that I can use a standard transformer in the output. Two 2N256 output transistors are mounted on aluminum heat sinks about six inches square and insulated from the chassis, since the body of the transistor is one of the terminals (collector). In the picture, the two aluminum straps upon which the device is resting are these heat sinks.

While guiding, the observer uses the punch block with relay switches that select, in addition to normal sidereal rate, 120 cycles or full stop, depending upon whether the guide star is running behind or ahead of the crosswires in the finder. These correction rates seem a bit too drastic in practice, so I plan to modify the circuit to deliver 30 and 90 cycles for slow and fast correction.

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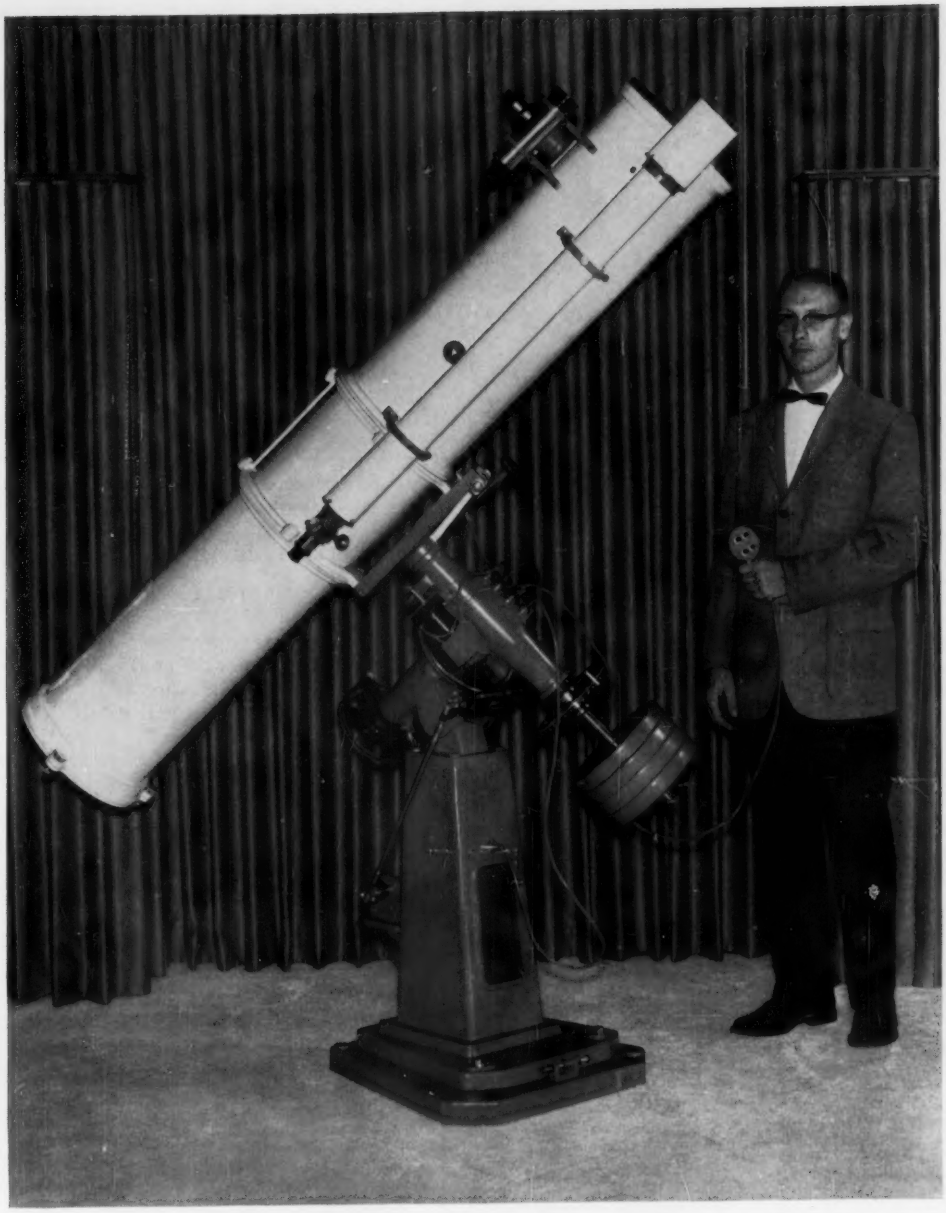

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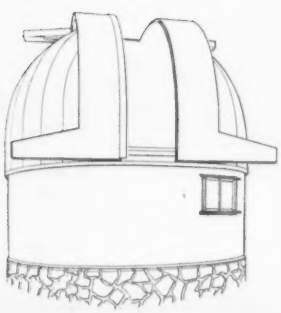

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From Stetson's *Manual of Laboratory Astronomy*, the chapter "Star Chart Construction" is available as a separate booklet, at 50 cents per copy.

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The Aldrich observatory at Paxton, Massachusetts, seen from the south. The floor plan below shows the observing section (left) and auditorium (right).

An Amateur Society's Low-Cost Roll-Off-Roof Observatory

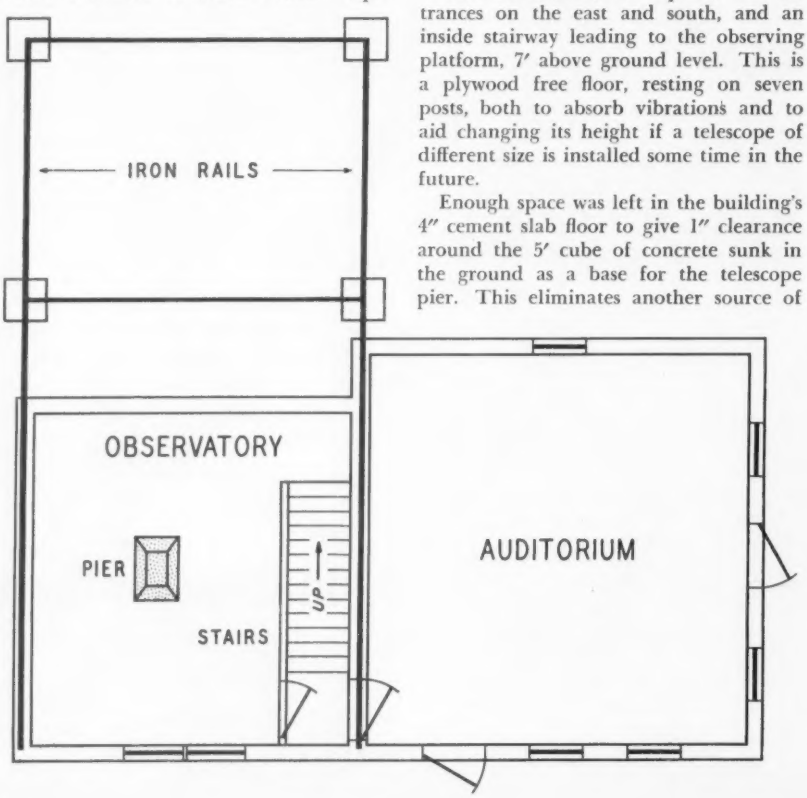
DESIGNED for public as well as members' use, the observatory of the Aldrich Astronomical Society, Worcester, Massachusetts, has a roll-off roof for its 10-inch reflector. During nine years of use, the arrangement has proven to be very practical. The observatory has an attached auditorium.

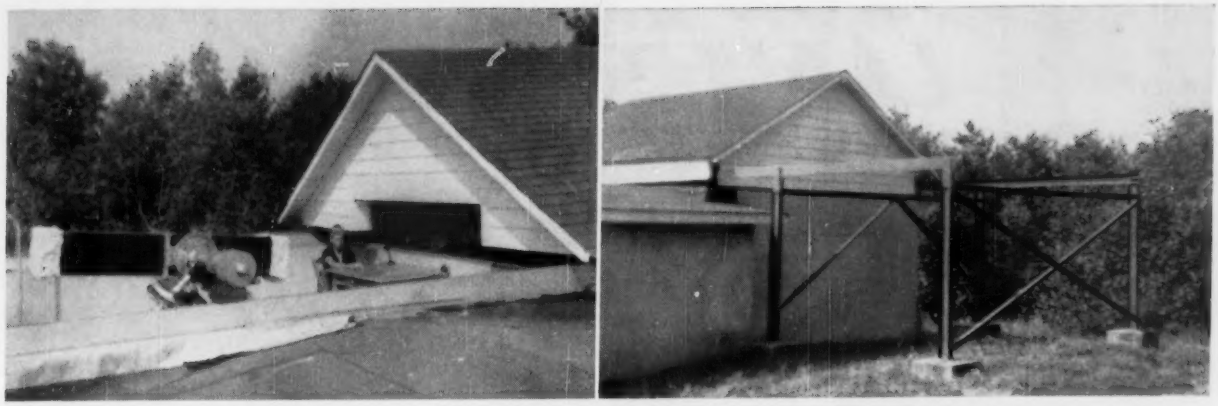
As the pictures show, the roof rolls on rails to the north, completely uncovering the observing section, which measures 16′ by 17½′. Not only does this enable visitors to see the whole sky while awaiting their turns at the telescope, but it permits the instrument to reach thermal equilibrium with the outside air quickly. The only disadvantage seems to be that on damp days paper work must be done in the room below the observing floor for protection from humidity.

A crank on a 10-to-1 gear reduction box operates the roof traverse. A length of chain is wrapped around a sprocket gear on this mechanism and fastened between the ends of the roof, which rides on eight 3″ flanged rollers. Brackets extending under the rails prevent the roof from lifting. The design can be generally recommended to amateurs.

The auditorium, 20′ square, has entrances on the east and south, and an inside stairway leading to the observing platform, 7′ above ground level. This is a plywood free floor, resting on seven posts, both to absorb vibrations and to aid changing its height if a telescope of different size is installed some time in the future.

Enough space was left in the building's 4″ cement slab floor to give 1″ clearance around the 5′ cube of concrete sunk in the ground as a base for the telescope pier. This eliminates another source of





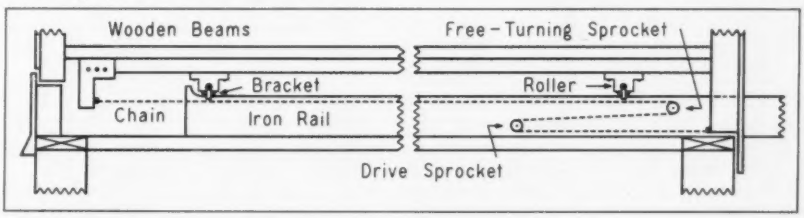
Rolling back the roof at left exposes the Aldrich observatory's 10-inch square-tube reflector. The roof rides on rails shown at the right, its motion being controlled and guided as sketched below by the author. The building's location in a wooded area isolates it from the city lights of Worcester.

vibration. Under the outside and center walls there are footings of stone and cement 24″ deep. The walls are of 8″ cement blocks, with frosted glass windows. The interior of the auditorium was given one coat of plaster and then painted, while other wall surfaces were painted only.

For two years the members of our society worked in their spare time on the building and the telescope. The observatory, on a site owned by the Worcester Natural History Museum, was financed by contributions from the people of Worcester County. In exchange for this, we agreed to sponsor public observing, and have had as many as 125 visitors on a single evening. Wayne Lovell, curator of the museum's astronomy department, is director of the observatory.

This project has filled an educational need of our community and at the same time increased our group's astronomical potentialities.

ARNOLD NIEUWENHOFF
3 Crestview Dr.
Holden, Mass.



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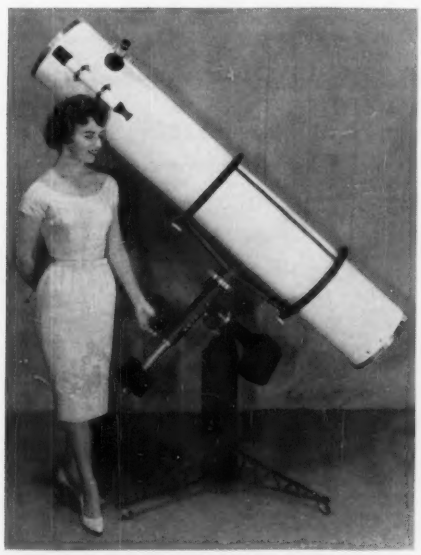

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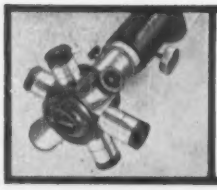

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constellation of the month

LYRA

A familiar skymark in the northeast on June evenings is the brilliant white star Vega, with a compact quadrilateral of naked-eye stars trailing beneath. This is the core of the small constellation Lyra, truly one of the most rewarding areas in the heavens for inspection with amateur telescopes.

Imagine yourself exploring Lyra with a 3-inch UNITRON. Perhaps you will first look in the view finder for the coarse pair of bright stars Delta[1] and Delta[2], to savor the fine red color of the latter. Next, a turn of the slow-motion controls brings Zeta into the low-power field of the UNITRON. This easy double consists of two white stars, magnitudes 4 and 5½, separated by a wide 44 seconds of arc.

Vega itself is a double, but considerably harder, the dazzling primary having a dim 10th-magnitude companion a minute of arc southward. Star images are crisp and steady on this good-seeing night, so you switch to high power for observing the famous double-double, Epsilon Lyrae. In the finder you see two 4th-magnitude stars, fully 3 minutes apart. The main telescope resolves each of these into a close and beautiful pair, with separations of 3 and 2½ seconds.

To top off your exploration of Lyra, there is the famed Ring Nebula, the 57th object in Messier's cluster-and-nebula list. It is situated between Beta and Gamma, rather nearer the former. Look for a dim smoke ring, with about twice the apparent diameter of the planet Jupiter. This remote shell of softly glowing gas is especially worth studying in a larger UNITRON, a 4-inch or 6-inch. Their greater light grasp helps bring out its delicate form, an elliptical ring.

Besides its visual attractions, Lyra has much to offer the astrophotographer. Use a small, fast camera attached by a Uniclamp to your UNITRON's tube for a guided time exposure to obtain a detailed photographic map of the constellation.

To the newcomer and more experienced astronomer alike, the choice of "the best" telescope is difficult and confusing . . . so many makes . . . so many models. An astronomical telescope must be designed to observe "point sources at infinity," and hence requires a precision optical system for crystal-clear definition. Optics and mountings must be equally precise to track the star or planet. One without the other is useless. Invest in a UNITRON and be certain of combined optical and mechanical excellence.

MANY Models To Choose From!

1.6" ALTAZIMUTH ($7.50 Down) with eyepieces for 78x, 56x, 39x — **$75**

2.4" ALTAZIMUTH ($12.50 Down) with eyepieces for 100x, 72x, 50x, 35x — **$125**

2.4" EQUATORIAL ($22.50 Down) with eyepieces for 129x, 100x, 72x, 50x, 35x — **$225**

3" ALTAZIMUTH ($26.50 Down) with eyepieces for 171x, 131x, 96x, 67x, 48x — **$265**

3" EQUATORIAL ($43.50 Down) with eyepieces for 200x, 131x, 96x, 67x, 48x — **$435**

3" PHOTO-EQUATORIAL ($55.00 Down) with eyepieces for 200x, 171x, 131x, 96x, 67x, 48x — **$550**

4" ALTAZIMUTH ($46.50 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x — **$465**

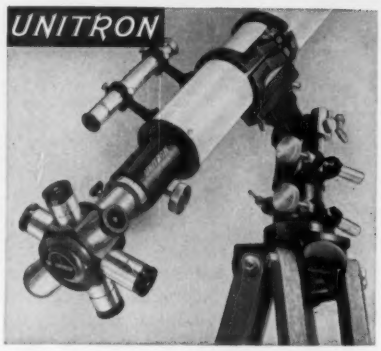
4" EQUATORIAL ($78.50 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x — **$785**

4" EQUATORIAL with clock drive **($98.50 Down)**, Model 160V, eyepieces as above — **$985**

4" PHOTO-EQUATORIAL with clock drive and Astro-camera **($117.50 Down)**, with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x — **$1175**

4" PHOTO-EQUATORIAL with clock drive, pier, Astro-camera **($128.00 Down)**, eyepieces for 375x, 300x, 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x — **$1280**

6" EQUATORIAL with clock drive, pier, 2.4" view finder, with eyepieces for 625x, 500x, 416x, 357x, 277x, 200x, 138x, 100x, 62x, 42x — **$5125**



UNITRON of every month

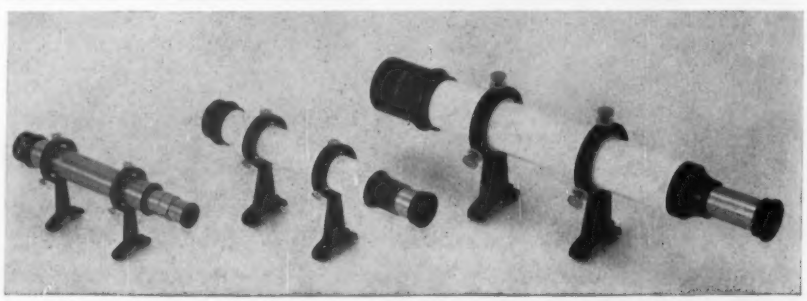
2.4" ALTAZIMUTH REFRACTOR

Here is America's most popular low-priced refractor.

The UNITRON 2.4" Altazimuth Refractor is not only a favorite with the beginning amateur, but is chosen by many owners of larger instruments as a second telescope because of its light weight and extreme portability. The best news about America's most popular refractor, though, is the low, low price. For only $125 you can treat yourself to an instrument which, optically speaking, duplicates the performance of larger telescopes of other makes. Complete with tripod, sturdy mounting, micrometric slow-motion controls, UNIHEX Rotary Eyepiece Selector, four eyepieces, sunglass, carrying case, and the new Achromatic Amplifier, this UNITRON can be yours for a mere 10% down payment of $12.50, using our Easy Payment Plan.

Investigate. See for yourself why more people are looking to the stars through a UNITRON than ever before.

New UNITRON View Finders



UNITRON's popular view finders with newly designed optics and mechanical features are better than ever. From left to right: 23.5 mm., 30 mm., 42 mm.

1. VIEW FINDER (Used on UNITRON 2.4" Equatorials): 23.5-mm. (.93") achromatic objective, 6x eyepiece with crosshairs. Chromed brass tube. Mounting brackets with centering screws. **Only $8.50 postpaid**

2. VIEW FINDER (As used on UNITRON 3" Refractors): 30-mm. (1.2") coated achromatic objective and 8x eyepiece with crosshairs. Other details as in View Finder 3. **Only $10.75 postpaid**

3. VIEW FINDER (As used on UNITRON 4" Refractors): 42-mm. (1.6") coated achromatic air-spaced objective. 10x eyepiece with crosshairs. Duralumin tube finished in white enamel. Dewcap. Furnished with mounting brackets, centering screws for collimation, and mounting screws. This finder measures approximately 16" overall. It is light in weight, compact and small enough for use as a hand telescope furnishing spectacular wide-field views of the sky. **Only $18.00 postpaid**

TELESCOPES FOR TEACHING IN THE SPACE AGE

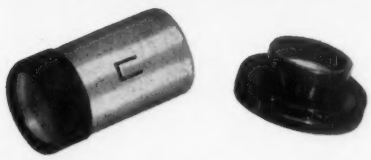
With the aid of their 4-inch UNITRON Refractor, students at Texas College of Arts and Industries find it easy to visualize problems in equatorial motion.

In this space age, astronomy is regaining its rightful place in the school curriculum. But students deserve more than just an opportunity to read about the universe. Studies become more interesting and lectures more meaningful when students can *see* for themselves the planets of our solar system and other celestial wonders.

For this reason, an astronomical telescope is rapidly becoming an indispensable teaching aid for secondary schools and colleges throughout the country. And what telescope is "teacher's pet"? Why, none other than UNITRON — America's largest-selling refractor. UNITRONS are portable, easy to operate and, unlike other types, require no maintenance. They offer professional quality at prices well within the reach of even limited school budgets.

If your school is slow to accommodate its thinking to the space age, why not take the initiative yourself and recommend the purchase of a telescope to your local school board. Funds from the National Defense Education Act are now available for the purchase of science teaching equipment. With interest in astronomy at an all-time high there is no better moment than now to treat your students to a UNITRON. Keep pace with the space age. Invest in a UNITRON — the telescope with the proven reputation.

NEW ACHROMATIC AMPLIFIER NOW FREE with each UNITRON



UNITRON's new "Achromatic Amplifier" is a two-element, Barlow-type, negative amplifying lens designed especially for UNITRON Refractors. When used with a UNITRON eyepiece, it **doubles** the normal magnification of the telescope. Here is an ideal way to increase the usefulness of each eyepiece and to obtain the high magnifications that you have always wanted for planetary and lunar observations. The magnification factor of 2x has been selected as the most useful for general amateur observing under a wide variety of atmospheric conditions. Two types of mounting cells are offered: one to fit the UNIHEX Rotary Eyepiece Selector and one for the UNITRON Star Diagonal. Either type can be inserted or removed in a jiffy. There are no cumbersome tubes to attach, nor ever any need to adjust the focus of the "Achromatic Amplifier."

This useful and valuable accessory is now included as standard equipment with all UNITRON Refractors at no additional cost . . . another of the many reasons why the telescope you choose should be a UNITRON.

HOW TO ORDER A UNITRON

Send check or money order in full or use our Easy Payment Plan. Shipments made express collect. Send 20% deposit for C.O.D. shipment. UNITRON instruments are fully guaranteed for quality, workmanship, and performance, and must meet with your approval or your money back. Prices of UNITRON refractors include basic accessories, eyepieces, tripod and mounting, fitted cabinets, and instructions.

USE OUR EASY PAYMENT PLAN

UNITRON's popular Easy Payment Plan is a convenient and economical way to buy your UNITRON Refractor. The down payment required is 10%. The balance due is payable over a 12-month period, and there is a 6% carrying charge on the unpaid balance. Your first payment is not due until 30 days after you receive the instrument, and if you should want to pay the entire balance due at that time, the carrying charge is cancelled.

Note These UNITRON Features

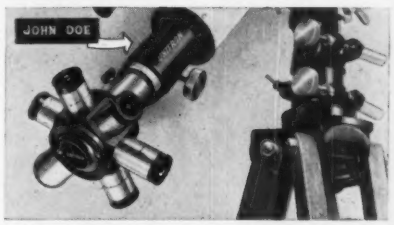
- LENSES are FULLY CORRECTED for spherical and chromatic aberration and are COATED for maximum brilliance and clarity of image. Optics especially designed for astronomical observation. AIR-SPACED OBJECTIVES.
- REFRACTOR type of design duplicates the performance of larger telescopes of other types. No mirrored surfaces to become oxidized. Superior definition to the very edge of the field.
- EYEPIECES of the HIGHEST QUALITY: Orthoscopic, Achromatized Symmetrical, Kellner, Huygens. Three to ten eyepieces included with each instrument.
- FINEST MATERIALS used throughout. DURALUMIN TUBE. Moving parts of BRASS carefully machined to close tolerances, and finished in CHROMIUM. No surplus components used.
- MODERN DESIGN based on time-tested engineering principles. HANDSOME APPEARANCE to which no illustration can do justice.
- EQUATORIAL MODELS have slow-motion controls for **both** declination and right ascension as well as convenient clamps on both axes. Sturdy TRIPOD (or PIER).
- ALTAZIMUTH MODELS have slow-motion controls for **both** altitude and azimuth as well as clamps for both co-ordinates. Sturdy TRIPOD.
- VIEW FINDER with crosshair eyepiece.
- RACK-AND-PINION FOCUSING.
- Choice of UNIHEX Rotary Eyepiece Selector or STAR DIAGONAL and ERECTING PRISM for TERRESTRIAL OBSERVATION. The same complete range of terrestrial magnifications as for celestial observation.

Higher- and lower-power eyepieces available for all models. Prices include basic accessories, tripod and mounting, fitted wooden cabinets, and operating instructions.

CALLING ALL UNITRON OWNERS!

If you purchased a UNITRON before the Achromatic Amplifier was available, we want you to have the chance to get one, and offer it at the special price of $6.00 — less than one-third the price you'd pay elsewhere for an accessory of this quality. This offer is for UNITRON owners only. (When ordering, please state whether for UNIHEX or star diagonal.)

IT HAD TO HAPPEN: A UNITRON WITH YOUR NAME ON IT!



We've gone and done it. We've personalized the telescope business. For a limited time, when you buy a UNITRON, you can have your name embossed in a plastic name plate attached to the gleaming black barrel at no charge.

People tell us they like it. It's in quiet good taste, yet it seems to give that extra fillip to the pride of ownership people feel for their UNITRONS. To get your name plate simply add this statement to your order: Please attach a name plate to my telescope. This is the name: (print name clearly).

Get UNITRON's FREE Observer's Guide and Catalog

Contents include:

- Observing the sun, moon, planets and wonders of the sky
- Constellation map
- Hints for observers
- Glossary of telescope terms
- How to choose a telescope
- Amateur clubs and research programs

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Please rush to me, free of charge, UNITRON'S new Observer's Guide and Telescope Catalog **20-Q**.

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CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

Occultation of Porrima on June 21st

PASSAGE of the moon in front of the double star Gamma Virginis will furnish a striking sight on the evening of June 21st for telescope users in the southern and western United States. (Observers in the Northeast will see the moon pass just south of this star, also known as Porrima.)

The double star consists of a 3.6-magnitude primary, with a 3.7-magnitude companion currently 5.0 seconds of arc distant, at position angle 308°. Immersion takes place at the dark edge of the 9-day-old moon, reappearance at the bright edge. Because the line joining the two components of Porrima is nearly parallel to the direction of the moon's motion, about 10 seconds of time will elapse between disappearances of the stars.

Standard times listed in the accompanying table will provide a rough guide for observers. Predictions for specific locations can be derived from data in the Occultation Supplement in Sky and Telescope for December, 1960. In California, immersion will take place in evening twilight. Farther east, where this event occurs in a darker sky, binoculars should enable the star to be followed up to the moon's edge. Although binoculars will not show Gamma as double, observers using them may note that the disappearance is stepwise, the star suddenly losing half its brightness, then after about 10 seconds vanishing completely.

Location	*Disappearance*	*P.A.*	*Reappearance*	*P.A.*
Western Illinois	10:47 p.m. CST	43°	11:12 p.m. CST	5°
Central Texas	10:38 p.m. CST	80°	11:39 p.m. CST	327°
Denver	9:21 p.m. MST	64°	10:09 p.m. MST	346°
New Mexico-Arizona	9:15 p.m. MST	85°	10:23 p.m. MST	327°
Southern California	7:48 p.m. PST	96°	9:07 p.m. PST	321°

P. A. is the position angle of the star on the moon's limb, counted from the north point of the limb through east, south, and west. The position angle of the northern cusp of the moon will be 23°.5.

Deep-Sky Observers

An extremely fine, imported Zuiho binocular with a wide field of view—10½°!

$35.00
Tax Paid

Complete with beautiful case. Delivered anywhere in the Continental United States.

AMERICAN TYPE WIDE ANGLE
7 x 35 Central Focus

SPECIFICATIONS

Magnification, 7x. Objective aperture, 35 mm. Eyepiece aperture, 24 mm. Exit pupil, 5 mm. Field of view at 1,000 yds., 551 ft. Field-of-view angle, 10.5°. Height, 128 mm. Breadth, 195 mm. Net weight, 950 grams. Weight of pigskin case, 400 grams.

We have sold hundreds of pairs of these binoculars with the utmost satisfaction. They are unconditionally guaranteed. If not pleased, return them and your money will be immediately refunded.

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Variable Star Maxima

June 2, T Ursae Majoris, 123160, 7.7; 7, T Centauri, 133633, 5.5; 11, RS Herculis, 171723, 7.9; 12, R Trianguli, 023133, 6.2; 12, R Ursae Majoris, 103769, 7.5; 14, R Camelopardalis, 142584, 7.9; 21, RT Sagittarii, 201139, 7.0; 22, S Pictoris, 050848, 8.1; 22, SS Virginis, 122001, 6.8; 24, T Pavonis, 193972, 8.0; 27, S Carinae, 100661, 5.7.

July 4, RU Cygni, 213753, 8.0; 9, T Hydrae, 085008, 7.8; 9, X Ophiuchi, 183308, 6.8.

These predictions of variable star maxima are by the AAVSO. Stars are listed only if brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

Minima of Algol

June 1, 22:57; 4, 19:46; 7, 16:35; 10, 13:24; 13, 10:13; 16, 7:02; 19, 3:51; 22, 0:40; 24, 21:29; 27, 18:17; 30, 15:06.

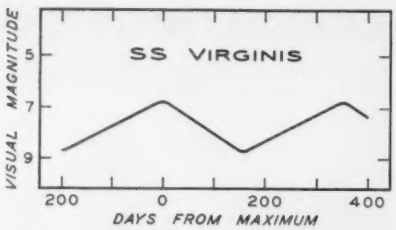
July 3, 11:55; 6, 8:44; 9, 5:32.

These minima predictions for Algol are based on a recent timing by D. Engelkemeir, and an assumed period of 2.8674 days. The times given are geocentric; they can be compared directly with observed times of least brightness.

Moon Phases and Distances

Last quarter	June 5, 21:19
New moon	June 13, 5:17
First quarter	June 21, 9:02
Full moon	June 28, 12:38
Last quarter	July 5, 3:33

June		**Distance**	**Diameter**
Perigee	2, 3h	227,000 mi.	32′ 43″
Apogee	17, 22h	251,800 mi.	29′ 29″
Perigee	30, 1h	224,000 mi.	33′ 09″
July			
Apogee	15, 11h	252,400 mi.	29′ 25″



This mean light curve for SS Virginis was derived from observations made by members of the American Association of Variable Star Observers.

SS Virginis

AMONG the reddest stars in the sky are the variables of spectral type *N*, of which SS Virginis is a good example. This month it is conveniently observable in small telescopes, maximum brightness being scheduled for about June 22nd at magnitude 6.8.

SS Virginis is easy to locate, and is marked in both Norton's and the Skalnate Pleso atlases. It lies 2° northeast of Eta Virginis, at right ascension 12h 22m.7, declination +1° 03′ (1950 co-ordinates). The strong red color is helpful in identifying the star.

Variability of this object was first recognized in 1905 by M. and G. Wolf at Heidelberg, Germany, and a few years later E. Zinner established a periodicity of very nearly a year. According to Leon Campbell's analysis of the observations between 1907 and 1948, the average period is 355.9 days. Like all Mira variables with *N*-type spectra, the light changes differ markedly from cycle to cycle. The observed intervals between successive maxima have ranged from 326 to 381 days, and at peak brightness the visual magnitude has been anywhere from 6.0 to 7.3. On the average, the magnitude limits are 6.8 and 8.9.

Minor Planet Predictions

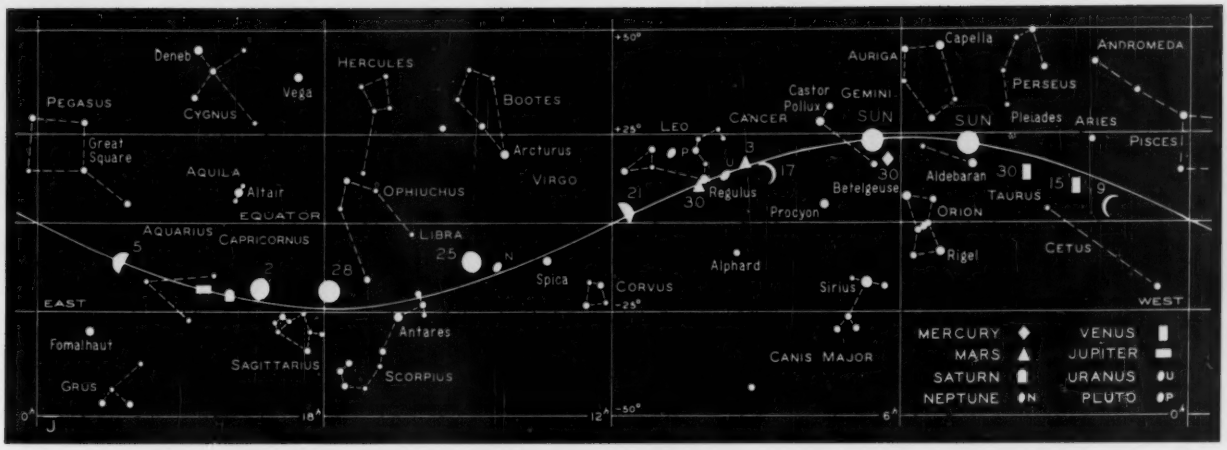
Iris, 7, 9.4. May 31, 18:40.1 −21-50. June 10, 18:32.0 −21-36; 20, 18:22.1 −21-22; 30, 18:11.3 −21-06. July 10, 18:00.8 −20-50; 20, 17:51.7 −20-36. Opposition on June 25th.

Amphitrite, 29, 10.0. June 10, 19:06.4 −32-00; 20, 18:57.9 −32-25; 30, 18:47.5 −32-41. July 10, 18:36.7 −32-43; 20, 18:26.7 −32-33; 30, 18:18.5 −32-13. Opposition on July 2nd.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

Universal Time (UT)

TIMES given in Celestial Calendar are Universal time (Greenwich civil time) unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th and to 10:15 p.m. PST on the 14th.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury on June 1st is at greatest eastern elongation, 23° from the sun, and sets nearly two hours after it. Then of magnitude +0.7, it appears telescopically as an 8″ crescent 37-per-cent illuminated. On the 14th, the planet will be stationary in right ascension, before beginning westward (retrograde) motion. At that time, it will be very difficult to observe, since it sets only one hour after the sun and is of magnitude +1.7. Inferior conjunction occurs on June 27th.

Venus is in Aries as it reaches greatest western elongation on the 20th, 46° from the sun. Then Venus will rise about 2½ hours before the sun, appearing brilliant in the east at magnitude −3.9. Small telescopes will show a half-illuminated disk 24″ in diameter, like a tiny moon at last quarter.

Earth reaches heliocentric longitude 270° on June 21st at 15:30 Universal time. Summer begins in the Northern Hemisphere, winter in the Southern.

Mars is visible in the western sky after sunset, a red object of magnitude +1.7 in Leo, at midmonth setting about an hour before local midnight. Now too far from Earth for satisfactory telescopic work, Mars' disk is only 4″.8 in diameter. This planet and Uranus will be visible less than a degree apart after sunset on the 15th, an interesting sight in binoculars. As Mars sets on June 26th, it will be very close to Regulus, conjunction occurring at 8^h UT on the 27th, with the planet 0°.7 north of the star.

Jupiter, of magnitude −2.2 on the 15th, is in Capricornus and rises about 2½ hours after sunset. Its elliptical telescopic disk is 45″.4 in equatorial diameter and 42″.4 in polar. The waning gibbous moon will pass 2° north of Jupiter on the night of June 2-3.

Saturn is easily found as a +0.5-magnitude object in Capricornus, about 8° west of Jupiter. In midmonth it rises about two hours after sundown. In a telescope, Saturn's disk has an equatorial diameter of 18″.2, and the extent of the ring system is 40″.9. This year the rings' northern surface is presented to the earth, and their inclination to the line of sight, 21°.3 on June 15th, will increase to a maximum of 23°.1 during late September.

Uranus is in Leo, its 1950 co-ordinates being right ascension 9^h 40^m.2, declination +14° 43′ on the 15th, when it sets about an hour before local midnight. This 6th-magnitude planet will be especially easy to locate in binoculars on the evening of June 15th, when it is in conjunction with Mars.

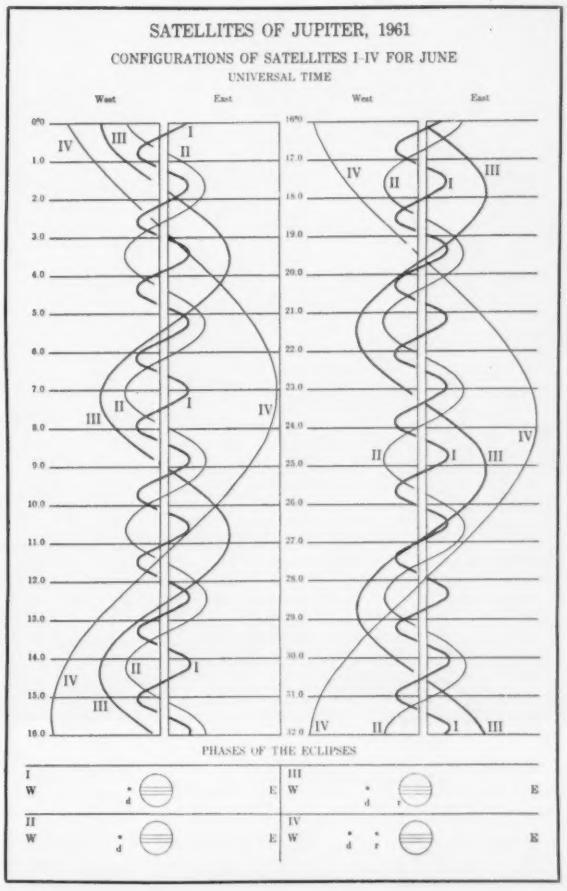
Neptune is an 8th-magnitude object in western Libra, at 14^h 27^m.7, −12° 41′ (1950 co-ordinates) on June 15th. It crosses the meridian about 1½ hours after sunset, and may be seen in small telescopes in the southern and southwestern sky until it sets about two hours before sunrise.

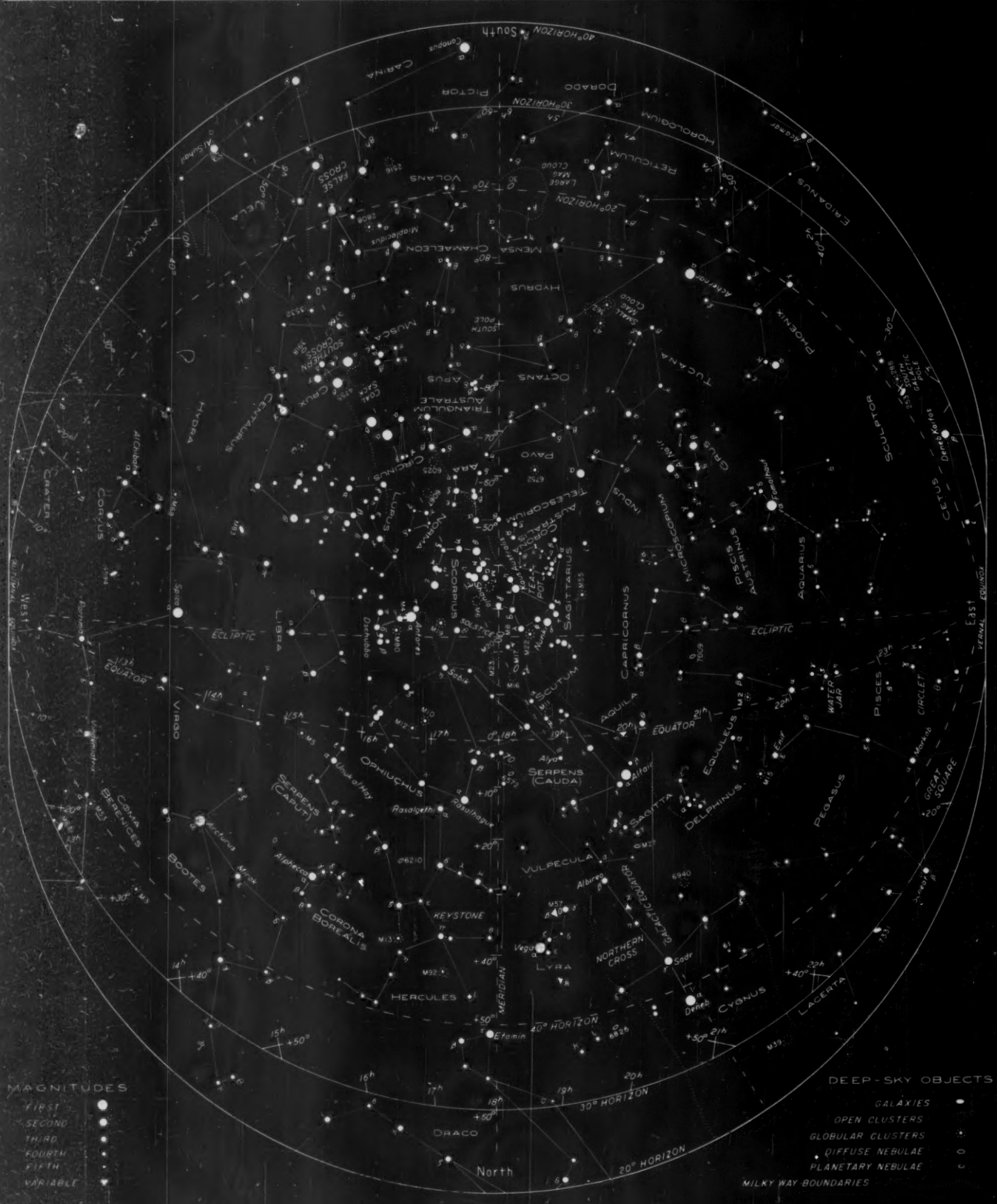
WILLIAM H. GLENN

JUPITER'S SATELLITES

The four curving lines represent Jupiter's four bright (Galilean) satellites: I, Io; II, Europa; III, Ganymede; IV, Callisto. The location of the planet's disk is indicated by the pairs of vertical lines. When a satellite transits in front of Jupiter, its curve crosses the lines. If a moon is invisible because it is occulted by Jupiter or is in its shadow, the curve is broken.

For successive dates, the horizontal lines mark 0^h Universal time, or 7 p.m. Eastern standard time (4 p.m. Pacific standard time) on the preceding day. Along the vertical scale, 1/16 inch is about seven hours. In this chart, west is to the left, as in an inverting telescope for a Northern Hemisphere observer. At the bottom, "d" is the point of disappearance of a satellite in Jupiter's shadow; "r" is the point of reappearance. From the "American Ephemeris and Nautical Almanac."





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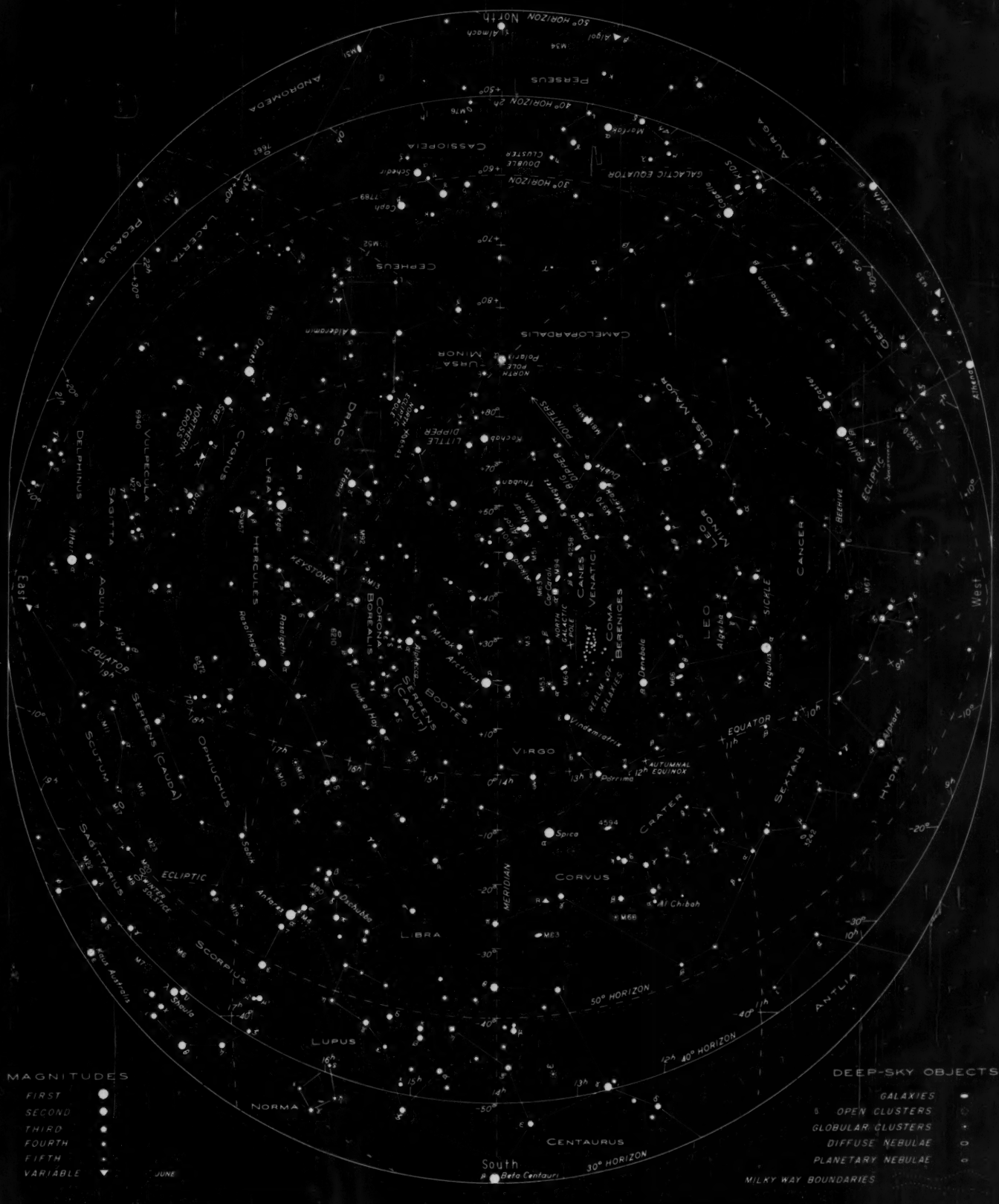
SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 7th and 23rd of July, respectively; also, at 9 p.m. and 8 p.m. on August 7th and 22nd. For other dates, add or subtract ½ hour per week.

High in the sky stretches the southern Milky Way, the direction to the galactic nucleus being indicated by the bright star-clouds of the Sagittarius region. Shaula the Sting accents the Scorpion's tail, and is rivaled in brightness by Kaus Australis in the Teapot.



STARS FOR JUNE

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 22nd of June, respectively. For other dates, add or subtract ½ hour per week.

Marking the fringe of Bootes the Herdsman's tunic is unmistakable Arcturus. On October 5, 1858, this bright orange star was visible through the head of Donati's comet, only 20 minutes of arc from the nucleus. J. F. J. Schmidt could observe Arcturus with the naked eye 24 minutes before sunset.

OPTICS

Special Coated Objectives

BIG 2⅛" DIAM. — 40" F.L. — $6.00

These tested achromatic lenses are the same high quality as our "Big Lenses," except for being seconds because of slight edge chips or small scratches.

Cat. No. S1804 ..... **Only $6.00 ppd.**

Mounted Eyepieces

The buy of a lifetime at a great saving. First choice of the amateur and professional astronomer. Perfect lenses set in black anodized standard 1¼" O.D. aluminum mounts.

Cat. No.	F.L.	Type	ppd.
S2192	6 mm. (¼")	Orthoscopic	$13.25
S1851	6 mm. (¼")	Ramsden	4.75
S1853	12.5 mm. (½")	Ramsden	4.50
S1207	12.5 mm. (½")	Symmetrical	6.00
S1251	16 mm. (⅝")	Erfle (wide-angle)	12.50
S1257	16 mm. (⅝")	Orthoscopic	12.50
S1209	18 mm. (¾")	Symmetrical	6.00
S1211	22 mm. (27/32")	Kellner	6.00
S1835	27 mm. (1-1/16")	Kellner	4.50
S1355	32 mm. (1¼")	Plossl	12.50
S1253	35 mm. (1⅜")	Symmetrical	8.00
S1255	55 mm. (2-3/16")	Kellner	6.00
S1485	56 mm. (2¼")	Symmetrical	6.00

COATED LENSES 75 cents extra.

"Giant" Wide-Angle Eyepiece

COATED LENSES 75 cents extra.

Erfle eyepiece best for low-power performance. Superior six-element design. 65° field, 1½" E.F.L., clear aperture 2⅛", focusing mount and diopter scale. Combine this eyepiece with our 5" objective No. S1475 for a tremendous light-gathering Rich-Field Telescope.

Cat. No. S1405 (illustrated) ..... **$12.50 ppd.**
Cat. No. S1858 Same as above without diopter scale ..... **9.95 ppd.**

● **FREE RUBBER EYESHIELD** ● with S1405

Cat. No. S1594 1¼"-diam. ADAPTER for eyepiece above ..... **$ 3.95 ppd.**

ADAPTER PLATE AND TUBE. Aluminum tapered tube and adapter plate, black anodized and finished in black crackle. Slides into our 5" O.D. Aluminum Tubing No. S1511. These parts are used with the eyepieces above to make a Rich-Field Telescope. Details in our catalogue.

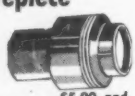
Cat. No. S2300 ..... **$18.00**

Wide-Angle Erfle

Brand-new eyepiece with 68° field; coated. E.F.L. 1¼". Focusing mount, 3 perfect achromats, 1-13/16" aperture.

Cat. No. S1020 ..... **$13.50 ppd.**
Cat. No. S1593 1¼"-diam. ADAPTER for eyepiece above ..... **3.95 ppd.**

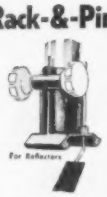
An Economical Eyepiece



This mounted eyepiece has two magnesium-fluoride-coated achromatic lenses 29 mm. in diameter. Excellent definition. E.F.L. 1¼". Cell fits 1¼" tubing.

Cat. No. S1911 Coated ..... **$5.90 ppd.**
Cat. No. S1991 Not Coated ..... **5.25 ppd.**

Rack-&-Pinion Eyepiece Mounts



Here is a wonderful opportunity for you to own a most mechanically perfect Rack-&-Pinion Focusing Eyepiece Mount with variable tension and adjustment. Will accommodate a standard 1¼" eyepiece, positive or negative. The body casting is made of lightweight aluminum with black-crackle paint finish, focusing tube of chrome-plated brass. Focusing tube for refractors has a travel of 4", for reflectors 2". Mount will fit all size tubing.

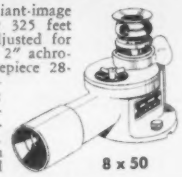
REFRACTOR TYPE

Cat. No. S1494 for 2⅛" I.D. Tubing ..... **$12.95 ppd.**
Cat. No. S1495 for 3¼" I.D. Tubing ..... **12.95 ppd.**
Cat. No. S1496 for 4⅜" I.D. Tubing ..... **12.95 ppd.**

REFLECTOR TYPE

Cat. No. S1976 (less diagonal holder) ..... **$8.50 ppd.**
Cat. No. S1982 DIAGONAL HOLDER ..... **1.00 ppd.**

8-Power Elbow Telescope

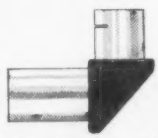


This telescope has a brilliant-image 48° apparent field: actually 325 feet at 1,000 yards. Can be adjusted for focusing 15 feet to infinity. 2" achromatic objective, focusing eyepiece 28-mm. f.l., Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for night use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

8 x 50

Cat. No. S1686 Not Coated ..... **$13.50 ppd.**
Cat. No. S1975 Coated ..... **17.50 ppd.**

Star Diagonals



Guaranteed to make viewing the heavens with a refractor telescope 100% easier for the observer. Stop needless crouching forever. Choose the STAR DIAGONAL that best suits your requirements. Slides into standard 1¼" eyepiece mounts. Chromium tubes and aluminum housing, attractive black-crackle finish.

AMICI STAR DIAGONAL WITH ERECT IMAGE

For comfortable viewing of terrestrial or astronomical objects. The Amici prism gives an erect image.

Cat. No. S2095 ..... **$12.00 ppd.**

RIGHT-ANGLE PRISM STAR DIAGONAL

Contains a high-quality aluminized right-angle prism, wide field. Practical for astronomical use.

Cat. No. S2096 ..... **$12.00 ppd.**

MIRROR STAR DIAGONAL

Diagonal houses an excellent first-surface mirror, flat to within ¼ wave. Important accessory for refractor telescopes.

Cat. No. S2097 ..... **$12.00 ppd.**

7 x 30 Wide-Field Finderscope

Newly designed wide-field finderscope for reflector or refractor. Featured in this handsomely conceived black anodized aluminum tube are a 30-mm. coated achromatic objective, a wide-field Kellner eyepiece, and the all-important true crossline reticle for fast, exact locating. Compact and lightweight, 9" long, 1½" diam., 9 oz. May also be used as a hand-held telescope, offering excellent extra-wide-field views of the sky.

Cat. No. S2193 ..... **$9.75 ppd.**

Finder Ring Mounts

Made of cast aluminum with black crackle finish. Each ring has three locking wing screws for adjusting. Base has two holes for mounting screws, and fits any diameter tubing. Easy to attach. Ring mount No. S1963 will accommodate finder above.

Cat. No. S1963 .. 1-15/16" I.D. .. **Per Pair, $3.95 ppd.**
Cat. No. S1964 .. 2-11/16" I.D. .. **Per Pair, 3.95 ppd.**

New Prismatic Telescope

Coated 80-mm. Objective

Big 80-mm.-diam. (3⅛") objective, for spotting or astronomical use. Will show stars of the 11th magnitude — 100 times fainter than the faintest visible to the naked eye. Table-top tripod included, extended 18", closed 13¼". Length of scope 16¼". Combined weight of scope and tripod is 5¼ lbs. All coated optics.

FIVE EYEPIECES

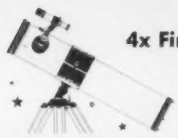
Power	Field at 1,000 yards	Exit pupil diam.	Relative Brightness
15x	122 ft.	5.4 mm.	29
20	81	4.0	16
30	61	2.7	7
40	49	2.0	4
60	32	1.3	1

Cat. No. S2052 ..... **$59.50 ppd.**

60-mm.-diam. Scope. Same as above but with smaller objective. Equipped with same five eyepieces — 15x, 20x, 30x, 40x, 60x. Coated. With tripod.

Cat. No. S1721 ..... **$42.95 ppd.**

4" Reflector Telescope



45x-225x
4x Finder — Wood Tripod

Study the sun and its spots. Observe galaxies, clusters, nebulae, and the Milky Way. Enjoy the thrill of being able to pick out small craters on the moon and see detail in the larger craters. A beautiful lunar landscape is brought to your doorstep. Bring distant events close to you; witness nature in action — eclipses, heavenly objects, and orbiting satellites. A high-quality telescope with an f/9 mirror. It has three eyepieces, 4-mm. (225x), 6-mm. (150x), 20-mm. (45x), and a free Barlow lens which will double the power. This will give 90x with the 20-mm. eyepiece, and 300x with the 6-mm. if observing conditions permit. Equipment tray keeps eyepieces clean and at hand. Sun and moon filters are included. Collapsible wood tripod makes scope portable, gives it stability and compactness. Finished in gray enamel with black trim. Imported. Shipping weight about 20 lbs.

FREE BARLOW LENS PLUS FREE BOOK "DISCOVER THE STARS" will come with scope.

Cat. No. S2273 ..... **f.o.b. Lynbrook, N. Y., $59.50**

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Beautifully styled imported binoculars. Precision made.

LOW, LOW PRICES!

American Type

"Zeiss" Type

Complete with carrying case and straps. American type offers a superior one-piece frame and clean design. Individual Focus (IF) or Center Focus (CF).

Cat. No.	Size	Field at 1,000 yards	Type	Price, ppd.
S1149	6 x 15 IF	360 ft.	Opera	$12.75
S1436	6 x 30 CF	395	"Zeiss"	18.75
S1435	6 x 30 IF	395	"Zeiss"	16.75
S1438	7 x 35 CF	341	"Zeiss"	20.75
S1437	7 x 35 IF	341	"Zeiss"	17.95
S1771	7 x 35 CF	341	American	23.50
S1439	7 x 35 CF	578	American*	35.00
S2191	7 x 50 CF	530	American**	42.50
S1106	7 x 50 CF	372	"Zeiss"	24.95
S-961	7 x 50 IF	372	"Zeiss"	22.50
S1503	7 x 50 CF	372	American	32.50
S1443	8 x 30 CF	393	"Zeiss"	21.00
S1229	8 x 30 IF	393	"Zeiss"	18.25
S1108	10 x 50 IF	275	"Zeiss"	26.75
S1442	20 x 50 CF	183	"Zeiss"	33.75

*Wide-angle 11° **Wide-angle

Add 10% Federal tax to all prices above.

Monoculars

Brand new, coated optics, complete with pigskin case and neck straps.

Cat. No. S1576 ..... **6 x 30** ..... **$10.00 ppd.**
Cat. No. S1577 ..... **8 x 30** ..... **11.25 ppd.**
Cat. No. S1578 ..... **7 x 35** ..... **12.50 ppd.**
Cat. No. S1303 ..... **7 x 50** ..... **14.75 ppd.**
Cat. No. S1579 ..... **16 x 50** ..... **17.50 ppd.**
Cat. No. S1580 ..... **20 x 50** ..... **20.00 ppd.**

New! Zoom Binoculars

Six different powers at your fingertips in the same binocular: 7x, 8x, 9x, 10x, 11x, and 12x. Positive fingertip control accomplished by rotation of eyecups. Popular Center Focus, American type, 40-mm. objectives, all coated optics. Complete with carrying case and straps. **Add 10% Federal tax.**

Cat. No. S2303 ..... **$39.75 ppd.**

● **FREE CATALOG** ●

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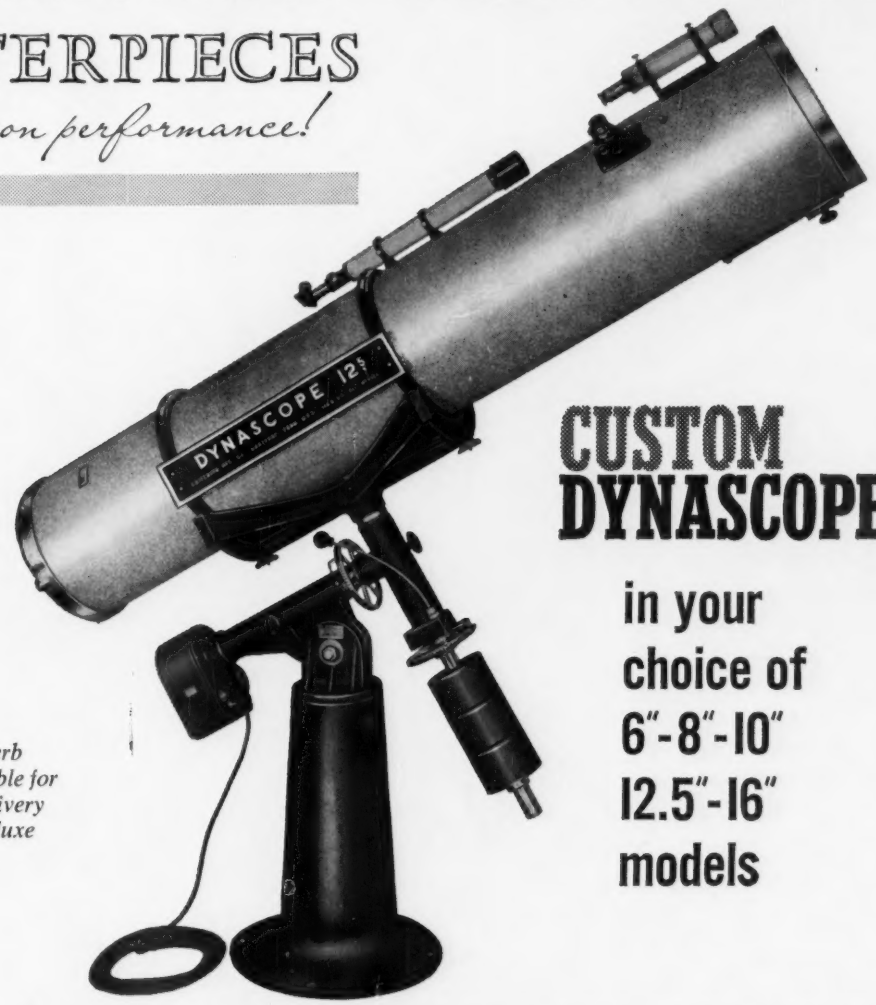
MASTERPIECES

of precision performance!



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The full purchase price of $1280 includes everything the serious observer wants and needs to make the most of his observing — clock drive, fixed pier, Astro-camera, 2.4" photographic guide telescope, Super-UNIHEX, large 42-mm. 10x view finder, eyepieces, and a complete selection of accessories in addition to these pictured above.

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